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Putting Public Relations in its Place[1]

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A number of North American museums have established or expanded public relations departments in the past few years. While the needs and policies of the various institutions may differ, the problem of determining the most practical and productive relationship between the public relations specialists and the curatorial or academic staffs is sufficiently general to merit an expression of opinion. It is felt that the division and limits of authority, status in the organization, and the essential functions of the public relations specialist are aspects of this problem with generally applicable solutions.

The comments that follow are based on the assumption that museums are interested in formal public relations programs as an aid to achieving their basic educational and cultural objectives, and not as a means to increased revenue either at the turnstiles or through fund-raising campaigns. It is also assumed that museums are looking as far into the future in their public relations planning as they are in collecting or research. Finally, it is assumed that no museum would permit the ethical standards of its public relations program to fall below the standards of the museum itself. The present article is applicable, then, only to formal, long-range public relations programs, designed to further museums' educational and cultural objectives. The brief publicity campaign to boost attendance, for example, is beyond its scope.

A first consideration might be, "Where does the public relations specialist fit in to the traditional museum organization?" The simplest answer is that he does not. Rather than being *in* the organization, he must be appended to it, attached to it. He must not be ingested. It is a first essential that he be able to examine and study the museum organization from without, even

[1]Abstracted from a paper read at the 1960 annual meeting of the American Association of Museums.

though he is a member of the staff and on the payroll. As one of the curators at the Royal Ontario Museum put it, the public relations staff are resident visitors from the "outside world." The public relations officer must be *with* the museum, but not *of* the museum.

The same concept of "with, but not of" applies, of course, to his relationships to the museum's many publics: the visiting public and the non-visiting public, museum members, students at associated universities or schools, and all the other groups, or publics, with which the museum works. Ideally he maintains the cold objectivity of a double agent. He is the advocate of the publics to the museum, and the advocate of the museum to these publics. He is a bridge between the organization and the publics to which it is related. This is his basic function which must be accepted and understood.

To fulfill this function, he collects, studies, interprets, and disseminates information. On the one hand, he must be constantly gathering information about the museum's many publics and must be presenting it to the museum administration and curatorial staff along with his interpretations and recommendations. On the other hand, he must be gathering information within the institution, and again with interpretation and recommendation, must be presenting this to the institution's publics. Within this description of function can be found all the familiar public relations activities, from audience research to press publicity.

This concept of a bipartisan communications bridge can be applied to the relationship between the public relations specialist and the museum organization as a whole. His operating relationships within the museum organization require more detailed discussion.

Where do you put this double agent? He is at once a counselor and an adviser, a go-between, a middle-man, and a spokesman for both the museum and that annoying and inconvenient enemy, the public. He comes, truce flag in hand, to plead for the public, and he is on the museum payroll.

In many corporations today, the public relations expert is listed as a special assistant to the president. He has immediate access to the chief executive. It is suggested, first, that the museum public relations officer must be attached to the office of the director, the board, or the chief curator. Second, without a vote or authority he must have a seat at every major committee meeting. He must be supplied, as no one else in the organization, with a constant flow of information. He must be in the confidence of the board and of the senior executives.

Why? The answer is simply that he must have a complete and up-to-the-minute picture of his organization, just as he must have a fresh and thorough knowledge of his publics, if his counsel is to be of any use.

These suggestions frequently meet with opposition from both trustees and members of the curatorial staff. There are reservations about public

relations personnel, and these dubious persons have often been admitted to the museum organization as a necessary evil. These suggestions may be misinterpreted as meaning that the public relations director must be a senior executive. Not at all! He must have access to the senior executive; his most frank and direct recommendations must be requested by the senior executive; he must be the confidant of the senior executive; but it is beyond the proper function of the public relations specialist in a museum to set policy or to vote in its making.

The third suggestion to be made about the place of the public relations officer is that he have the right to investigate and make recommendations concerning any area of the museum or the museum's activity. The right to inquire is important. The ultimate objective of the process of public relations is to bring about the optimum relationship between the museum and its publics for the achievement of the museum's objectives. In creating this optimum relationship, it is necessary to build in the public mind an image of the museum. It goes without saying, but is often overlooked by institutions professionally inexperienced in public relations, that the image projected must be a true image.

Most museums have a self-image, based on statements of objectives, charters, written policy, and so on. But how often do our institutions, in the details of their operations, behave in strict accord with the idealistic and enlightened self-image? A public relations program in which a projected image is contradicted by public experience is doomed. So the public relations officer who is responsible for the projection of the museum's image must be invited to examine the realities on which that image is based. You cannot combine a "welcome" mat with a watchdog that bites.

In summary, the public relations officer must be regarded as one attached *to* rather than one *within* the organization. Such a relationship is necessary that he may maintain his position as an objective investigator and spokesman for the publics as well for the museum. Second, he must have ready access to the director, and must be in the confidence of the director and the senior staff. Otherwise, he will not be fully informed at all times, and his usefulness will be limited. Third, his right to inquire into any aspect of the museum's operations must be accepted. In all of these, the public relations specialist is quite properly an adviser. He is without the authority to set policy or to vote. His recommendations, his advice, and his point of view may or may not be accepted.

In one area, however, he must have authority and must have control. The public relations officer should be supported by regulations and procedures that give him control over the external presentation of the museum to the publics. Once the director and board, or whatever controlling body exists, sets public relations policy, he must control the *effecting* of that policy. At the Royal Ontario Museum, the release of information and photographs for

press, radio, and television; the granting of press, radio, or TV interviews, and personal appearances; the making of loans for advertising art or other commercial purposes; the graphic design of all material from posters to shipping labels to books; the floodlighting of the building and the condition of the grounds—all the ways in which the museum presents itself to its publics beyond the museum galleries—are channeled through the public relations department.

Now, the other side of the coin. Thus far, these suggestions include no advisers for the public relations officer, and no regulations or vetoes to control his activities, once public relations policy or principle has been established.

The key to the museum's control of public relations activities—and especially to the control of that overworked but essential public relations tool, publicity—is the deification of the curator. The curator must be omnipotent and omniscient, insofar as the use of his collections and the information about his collections are concerned, unless his idiosyncratic views turn out to be in collision with the expressed policy of the museum as a whole.

> I am very fond of an anecdote, which came to me fifth-hand and may be grossly inaccurate. It concerns the British Museum and a request for a loan. It seems that a foreign government—in Central America—was organizing an exhibition of national art treasures which was to go to Europe. One remarkable piece which filled a gap in the show was owned by the British Museum, and so the foreign government wrote politely and requested a loan. The object in question was unique and was on display in a place of honour in the British Museum. And the curator there wrote back even more politely, as only the English can, and said NO. So the Central American government cabled its Ambassador in London to do something about it. He did, and the curator said NO. So the Ambassador went to the Foreign Office, and the Foreign Office went to the director and the director went to the curator, who said NO. And eventually a question was asked on the floor of the House of Commons, and the Parliament of England agreed that it was up to the curator—who said NO.[2]

Whether the story is true or not is unimportant. If it is untrue, then, hopefully, that is what would have happened in such a circumstance.

In all the procedures for public relations activities at the Royal Ontario Museum, this statement, or a paraphrase of it, will be found: "Shall have been approved by the Curator, and shall be released through and with the consent of the Office of Information Services."

How this specific set of conditions works, and what unfortunate things can happen without such a set of conditions for museum public relations, can be imagined by any experienced reader. If put in his proper place, as suggested above, a public relations specialist could make a significant

[2]From the paper read at the annual meeting of the American Association of Museums, 1960, of which the present article is an abstract.

contribution to the development and effectiveness of a museum. Even then, however, success will depend on a bond of trust and respect between the public relations staff and the curatorial staff. If there is one serious problem in the healthy development of public relations programs in the museums of the United States and Canada, it is the lack of such mutual trust and respect. When museum curators cease to "pigeonhole" professional public relations personnel as press agents, flacks, or publicists, and attempt to understand the broader implications of their work, and when public relations specialists cease stereotyping curators and research workers as inflexible and autistic eccentrics, the way will be open for exciting and productive collaboration.

Casting in Fiberglass

P. J. O'BRIEN, SENIOR PREPARATOR

OTAGO MUSEUM, DUNEDIN, NEW ZEALAND

For some time a need has been felt for a material with which to make casts of fish and similar objects, to give a more life-like representation than has been possible formerly and to combine transparency, where required, with lightness and strength. At the same time it is a distinct advantage if the method is comparatively simple and the material one that lends itself to easy application without the need for elaborate or expensive equipment.

Polyester resins have been found eminently suitable for this purpose. The particular resin used is known as Crystic 191 and is a product of Scott Bader and Company, Ltd., London.[1] This resin is cold-setting, transparent when thin, and very light and strong. Polyester resins are liquid and require the addition of a catalyst to bring about polymerization, or a setting of the resin, and also an accelerator to control the speed of setting. Catalyst Paste H and Accelerator E are used with Crystic 191. The flow of the liquid resin before setting can be altered by the addition of a material known as Pregel 17. Glass fiber is used as the reënforcing material and is responsible for imparting the great strength that this cured resin possesses.

THE MOLD

Molds may be made of plaster, metal, wood, or almost any material, provided that it is rigid enough to keep its shape and its surface, if porous, is properly sealed.

As a cast can be only as good as the mold from which it is made, great care must be taken in the preparation and subsequent treatment of the mold.

It has been shown that a successfully reproduced eye can perhaps do more to create the illusion of life in a cast than anything else, so it is recom-

[1]The American supplier of the Scott Bader polyester products is The Borden Chemical Company, 350 Madison Avenue, New York 17, New York.

mended that the eyes receive special treatment. Before making a plaster mold of, for example, a fish, cut off the pectoral and ventral fins and wash it thoroughly in alum water. Next inject the eyes with hot Vaseline, using a hypodermic syringe, until any signs of shrinkage or collapse of the eye have disappeared. The Vaseline, on cooling, will hold the eyes in position.

Proceed with the mold in the usual way, but add a small quantity of alum to the water in which the plaster is mixed. This helps to prevent a softening of the plaster, which may occur if body fluids are seeping from the fish. When it comes to molding the reverse side of the fish, make separate piece molds of the back of each fin and the tail and then complete the body of the fish. Make two piece molds of the pectoral and ventral fins. The mold must now be thoroughly dried.

Before applying the separator to the mold a cast is made of the eye. To do this, procure a piece of sheet Perspex, one-sixteenth of an inch in thickness, a little larger than the eye. Heat it over a hot plate until it has become completely limp. Place it over the mold of the eye and rapidly force into the mold, using a smooth sheet of rubber backed with a piece of soft sponge rubber. As soon as it has cooled, it can be removed and the excess trimmed with a grindstone or file. The iris only is painted on the back of this cast eye, leaving the pupil clear. An appropriately colored concave shape of any suitable material is made and cemented behind the pupil, giving great depth and closely resembling a real eye. The complete eye is later cemented into the fiberglass cast which, of course, it exactly fits both in shape and size.

THE SEPARATOR

A multistage separator is required for fiberglass casting from plaster or other porous molds. First, paint the mold with one coat of boiled linseed oil, then shellac until an even coat is obtained. Wax the mold lightly with a hard polishing carnauba wax, and polish, when dry, with a brush. Do not use soft domestic wax polishes or silicone waxes. Finally, spray on four thin coats of Polyvinal Alcohol (P.V.A.) in a water solution, leaving to dry half an hour between coats. On metal or other impervious molds wax and P.V.A. only are required.

Before starting the actual casting, make sure that the room temperature is at a minimum of 68° F. and is free from drafts, which can cause an evaporation of the monomer from the resin mix, resulting in undercuring.

MIXING

Crystic Resin 191 is available in three grades—low, medium, and high viscosity. Medium viscosity was the grade used for the fish casts. Viscosity can be further controlled by the addition of Pregel 17 to the resin. None is required for a flat mold, but up to forty per cent may be needed for a

mold with steep sides to prevent excessive drainage of the resin. Do not use more Pregel in a mix than is necessary.

Measure the required quantity of resin and stir in the Pregel if required. A mechanical stirrer, such as a paint mixer in an electric drill, is desirable for thorough mixing, although it can be done by hand with a simple paddle. The catalyst paste is then measured accurately and stirred in, and finally the accelerator is added. On no account mix the catalyst and accelerator together, as they react with explosive violence. The mixture is then allowed to stand for a few minutes to allow air bubbles to escape.

Wash the stirrer in acetone after use. One-inch or two-inch paint brushes used for applying the resin can also be cleaned in acetone, but, if they are left standing in acetone between mixes of resin, be sure to remove all acetone before using again or it will upset the setting of the resin.

THE GELCOAT

The gelcoat is applied to the mold thinly and evenly with a brush (avoiding air bubbles) and allowed to set before it is backed with the glass-reënforcing material, in order to prevent any possibility that the glass reënforcing will appear on the surface of the cast. The gelcoat must cover the mold in one application. If more gelcoat is added to a partly filled mold, it will cause a dissolving of the joining edges.

The gelcoat formula is as follows:

Crystic Resin 191	60%
Crystic Pregel 17	40%
Crystic Catalyst Paste H . . .	4%
Crystic Accelerator E . . .	4%

This mixture containing four per cent accelerator will set in twenty minutes, and to a tough-dry state in one hour, after which latter time the laminating process can be commenced. The resin is fully set in one and a half hours.

Twenty ounces of gelcoat mix will cover three square yards.

THE LAMINATING COAT

After the gelcoat has set sufficiently, proceed immediately with the laminating coat. At this stage glass mat is impregnated with resin and applied to the mold.

Fig. 1. Applying gelcoat resin mix to the plaster mold of a large turtle. Fiberglass laminate will be added after the gelcoat sets.

Fig. 2. Breaking away the plaster "waste mold" from the fiberglass cast.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Several types of glass mats and cloths are available. For general-purpose casting and particularly for fish and other objects where intricate shapes are involved, chopped strand glass one and one-half or two ounces to the square foot is recommended. This mat consists of short strands of glass held together with a special binder and compressed into a mat. Glass roving, which is long, continuous strands of glass, is also useful for reënforcing spines and similar detail in some casts.

A liberal coat of the laminating resin mix is first applied to the back of the gelcoat with a brush, then pieces of glass mat are laid evenly over the wet resin, allowing about an inch of mat to project beyond the edges of the mold. Further resin is applied to this with a full brush, using a stippling action until it is thoroughly saturated. When saturated, it softens considerably and can be worked into the detail of the mold.

Great care must be taken to avoid the trapping of air bubbles between the mat and the previous gelcoat, or between layers of mat if more than one are used. If left, they will form very weak pockets in the cast. It is advisable, if practical, to roll the wet mat with a small roller made of a number of narrow wheels (such as one-inch Meccano wheels) on an axle attached to a handle, to insure that bubbles are excluded from the mat and that it is in good contact with the surface below.

As many layers of mat and resin as are required can be built up in this manner. There is no need to wait for each layer of the laminate to set before applying the next. However, an overnight delay is permissible between layers when one is working on very large casts.

One layer of two-ounce mat is ample for a fish of about three feet in length.

The resin formula used when one is laminating is as follows:

Crystic Resin 191	80%
Crystic Pregel 17	20%
Crystic Catalyst Paste H . . .	4%
Crystic Accelerator E . . .	2½%

The setting-time of this mix, with the room temperature at 68° F. is three-quarters of an hour. A higher room temperature is permissible and shortens the setting time, but the temperature should not fall below 68° F. The cast can be removed from the mold in one and a half to two hours.

Fig. 3. The finished fiberglass cast of a leathery turtle. This turtle measures six feet from head to tail and weighs only forty pounds. The semi-transparent jellyfish is also molded in fiberglass.

Fig. 4. The head of the leathery turtle, showing the fine detail obtainable with this molding material.

Determine the weight of glass mat necessary for the job in hand and mix three times its weight of resin. For example, one square foot of two-ounce mat requires six ounces of resin.

When the laminating of the mold has been completed, leave to set thoroughly before removing from the mold. The cast may be removed in one and a half to two hours, but can be left overnight if absolutely necessary. Loosen the overlapping edges of the cast first and ease from the edges of the mold. The cast will then usually spring free, if a little pressure is exerted and there are no serious undercuts. Use a waste mold if undercuts are extreme.

The cast will be somewhat pliable when first removed, so do not distort its shape by too much bending. It gains strength increasingly until full maturity is reached in from two to four weeks' time. When fully matured, a sheet of fiberglass can be bent quite appreciably and will spring back to its original shape.

The process of applying the gelcoat and laminating as just described is applicable to all forms of contact molding. In the case of fish casts, the procedure is somewhat different, owing chiefly to the problem of casting thin fins and tails.

CASTING OF FISH FINS

Apply the gelcoat to the fish mold as described above, including the separate molds of the back of the dorsal fin, anal fin, and tail, but, while the resin is still liquid, add a thin layer of glass mat to the fins and tail and impregnate thoroughly with the gelcoat mix. Slightly overfill the fins and tail with more resin, put the two halves together, and clamp them into place with C clamps. The pressure will squeeze out any excess resin, leaving the fins perfectly filled and having a back and front impression. Speed is necessary here, as the gelcoat resin will start to gel in twenty minutes. Leave to set and then proceed with the laminating coat, working the saturated mat into the base of the tail and fins.

The pectoral and ventral fins are dealt with in the same way and attached to the cast later.

TRIMMING

When fish are cast, it is essential to trim off the thin flange that forms between the two halves of the fin and tail molds, before the set resin becomes too hard. The pectoral and ventral fins, which have gelcoat mix only, can be removed from the mold in one and a half hours, but the rest of the fish with laminating coat must be left a further one and a half to two hours after the laminating coat is completed. On removal from the mold, it will be found that the fins, although set, are still quite soft and pliable and can be readily trimmed with scissors. The advantage will become

obvious when the trimming of spines and frayed-edged fins is called for. By the end of five hours from first starting the cast, the resin will have become too hard to be cut with scissors and will become progressively harder until full maturity is reached. Thick casts must be trimmed with tin-snips, files, or power grinders and burrs.

Sections of a cast are joined with the gelcoat mix, saturated glass mat being applied over the inside of the joint where possible. Supporting rods for large casts are also attached with the same resin mix. In the case of fish casts, drill and file out the fiberglass eye and cement the Perspex one in its place before joining the halves together. Any open seams can be filled with the resin mix, or, if a stiffer filler is needed, Pregel alone may be used.

Crystic Pregel 17	100%
Crystic Catalyst Paste H . . .	4%
Crystic Accelerator E . . .	4%

The setting time of this mix is a quarter of an hour.

COLORING THE CAST

Before the cast is colored, it must be cleaned of separator. Wash thoroughly with hot water and soap. Use a scrubbing brush, if necessary, and rinse the cast well afterward. Any separator left on the cast will cause paint to lift.

Use any recommended oil paint undercoat, the final coloring being done with artist's oil colors. Alternatively, Duco undercoating is satisfactory, if Duco or lacquer finishes are required.

The liquid resin may also be colored by the addition of pigments, lakes, or dyes. As most pigments retard the setting of the resin, the use is recom-

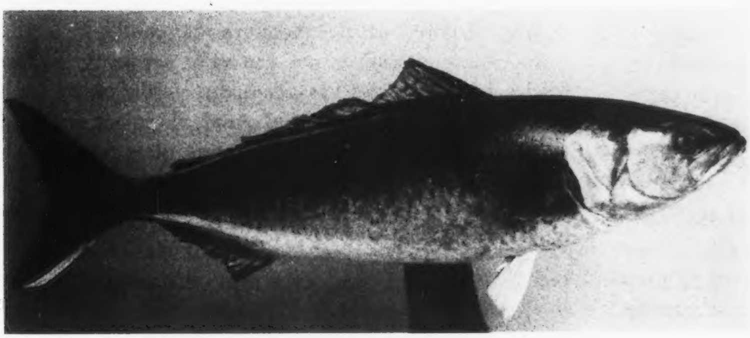

Fig. 5. Fiberglass cast of a three-foot kahawai. Note the fineness and transparency of the fins and the specially molded eye, as described in the text.

mended of not more than two to three parts by weight to every hundred parts of resin. Pigment powders should be ground first into a small quantity of resin and then mixed with the bulk of the resin. For opaque black, about five per cent slate powder or manganese dioxide should be incorporated. Rutile titanium dioxide gives a good white (anatase titanium is quite unsuitable). Most soluble dyes change color under the influence of catalyst and should not be used unless trials are made first.

FILLERS

Fillers may be used in the resin to extend it or alter its mechanical properties, if desired, but they usually retard the setting time. French chalk, whiting, powdered porcelain, china clay, titanium, or silver powder may be used. Do not add more than fifteen to twenty per cent of the fillers.

SHELF LIFE

Polyester resins should be stored in metal containers at a temperature of not more than 68° F. Light will cause rapid deterioration. Storage life under these conditions will be about a year or a little longer. As a general guide, as long as the resin will still pour, it is still usable. Catalyst Paste H has an indefinite shelf life, but may need stirring if left standing for long periods. Accelerator E has a shelf life of from six to nine months at not more than 68° F. Pregel 17 has a shelf life of six to nine months in tightly sealed containers at not more than 68° F.

OPERATING PRECAUTIONS

It is recommended that a barrier cream be used on the hands. Any resin, catalyst, or accelerator should be washed off with acetone followed by soap and water. Resin, catalyst, and accelerator are all inflammable and should be kept away from naked flame. However, moldings and laminates made with polyester resin only burn slowly when ignited and do not melt or flow. The fire hazard is therefore not great.

Special ventilation is not generally necessary, as long as the room is moderately large and has adequate ventilation by usual standards.

When grinding or cutting cured fiberglass with power tools, use a respirator, as the fine dust containing glass particles can be injurious to the lungs.

If these simple precautions are observed, the operator should have no fears in the handling of these materials.

The Revival of Systematic Exhibits

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THE AMERICAN MUSEUM OF NATURAL HISTORY

While many other kinds of display declined in the shadow of the habitat group, it was primarily the systematic exhibits that suffered a direct loss of museum territory as well. Other subjects were eclipsed, but systematics were being replaced. To add insult to injury, a specimen removed from a systematic array would often turn up again in the enemy's camp as a slightly remodeled member of a happy habitat group. The process is still continuing, and in small museums it can actually become a quite destructive influence, when a brief, but sound and, in its fashion, comprehensive systematic digest of nature is set aside to give room for a few space-consuming glimpses of special and spectacular situations that are insufficient to develop any continuity of theme or integrated coverage of subject. But there has also been a gradual revival of systematic, and similar, exhibits going on in many museums over the last ten or twenty years.

Since we are here concerned not only with subject matter, but also with style of display, we shall include in the discussion various types of exhibits that might not be regarded as systematic in the strict sense of the biologist, but have in common the exhibition of individual specimens as separate objects arranged to show relationships that do not arise from proximity in space, rather than the exposition of situations revealing the nature of coexistence in the same location. This may include faunistic and geographic exhibits using the specimen form of presentation, raw materials exhibits, and others in the same style.

Among the various forms of life it is particularly the birds that seem to have become the focal point of museum skill in systematic forms of presentation. Mammals cover such a range in size, from mouse to whale, that they almost defeat any attempt to create a general esthetic pattern, or a scheme of decorative seasoning with intimate detail that will give prominence according to importance and not merely according to size. Insects

Fig. 1

are too small to lend themselves very well to over-all effects. Their arrangement is a problem of visual texture[1] rather than form and perspective. But the sizes of the birds are just right to present an interesting challenge, without offering an insoluble problem. The great popular interest in birds, which often strongly accentuates their esthetic appeal, gives added incentive to the task of display.

It was also among the birds that the systematic exhibits suffered both the earliest and the greatest dislocations by the introduction of the habitat group. The systematic display of insects, mollusks, and other invertebrates continued its cautious progress almost undisturbed, conservatively behind the times in style and artistic vocabulary but still advancing. Many mammals are too large to be placed in adequate habitat settings. The development of systematic specimen exhibits of mammals therefore continued in a minor fashion in the shadow of the habitat group. Only in the case of the birds do the systematic exhibits of single specimens seem to have undergone a long period of almost complete neglect both curatorially and artistically. Perhaps in days of greater optimism it was hoped that all birds of public interest would ultimately be shown in their own habitat. Whatever the reasons and causes, it is fair to say that the old systematic exhibits of birds, before they were, or are, reached by the recent wave of moderniza-

[1] See "Designed for Display" by A. E. Parr, CURATOR, vol. II, no. 4, p. 323, 1959.

Fig. 1. Old systematic bird hall in The American Museum of Natural History, photographed in 1900.

Fig. 2. Systematic bird gallery in the Muséum National d'Histoire Naturelle.

Fig. 2

tion, generally have a more antiquated and neglected appearance than any other type of specimen exhibits.

Considering all the circumstances it is, therefore, not surprising that the revival of systematic exhibition within the biological sciences (excluding paleontology) has been spearheaded by, and until now almost limited to, the subject of ornithology which has come to be a testing stone for the designer's and the display artist's ingenuity in dealing with isolated natural history objects. Only more recently and still rather rarely do we find the revival of systematic exhibits extended to mammals, as in the notable new installations in the United States National Museum.

Our first illustration may serve to remind us of the heights of elegant tedium attained by the systematic display of birds, before the advent of the habitat group. It is true, of course, that some systematic galleries, like that of the Muséum National d'Histoire Naturelle in Paris, were able to achieve a cozy cornucopia atmosphere of profusely inhabited space, conducive to nostalgia even today. But these were the exceptions. Most systematic displays of the pre-habitat era could stimulate little but boredom except in the most ardent devotee. Figure 3 should refresh our memory of details that were similar the world over. Compared with Figure 2, it reveals some slight influence by the habitat concept, but this trend generally failed to develop much further over a period of nearly fifty years, begin-

ning about 1880, while nearly all ornithological exhibition skills were directed towards the habitat group itself. Displays such as those represented by Figure 3 can still not be described as rare sights, and were quite commonly seen as late as in the 1930's even in museums noted for their active exhibition program. Shelves upon shelves of curly-toed birds on T-perches, and flat-footed birds on square wooden bases, were the predominant elements of style in specimen display.

As the museums began to seek ways of emancipating their systematic exhibits from the tawdry uniformity of neglect, there were several directions in which they could seek alleviation of the monotony that is to some extent inherent in any systematic presentation. Relief can be obtained through the pure esthetics of selection and arrangement, and through formal, non-representational designs of setting and background, both in form and in color. These are, in some ways, the simplest and least expen-

Fig. 3. Glimpses of details from the old systematic exhibits of birds in the Museum of Bergen, Norway.

Fig. 4. New hall of Swedish birds in Malmö Museum, Sweden.

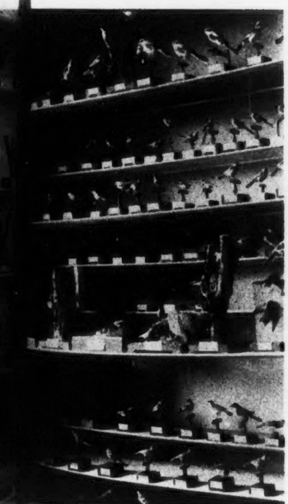


Fig. 3

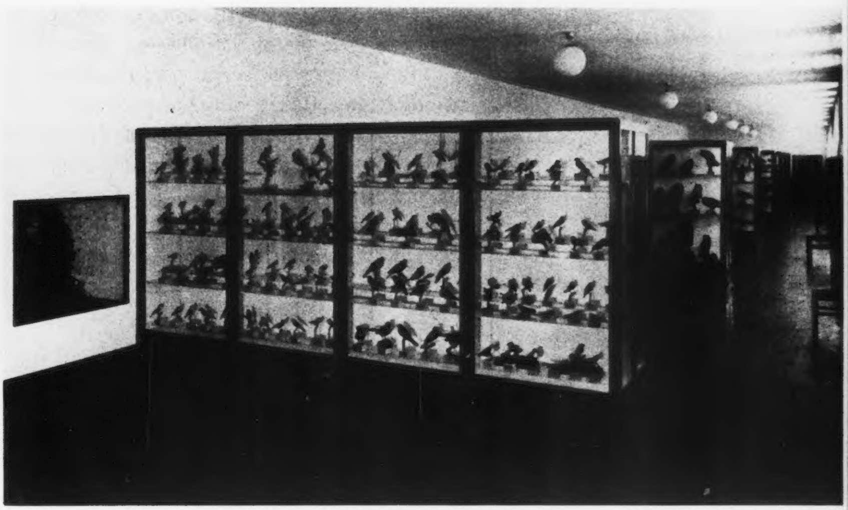


Fig. 4

sive methods of improvement and are those that have been most widely used. They leave the specimens strictly alone, in splendid isolation from the framework in which they are presented. The esthetics of the display merely serve to increase the independent attraction and interest of the objects, without suggesting external associations of special emotional significance to the viewer. When artistically successful, the austere objectivity of such exhibits has much to recommend it for purposes of formal education. But its lack of warmth is probably a liability with the general public that has not yet had its interest enlisted by inner compulsion or external requirements.

On first thought it would seem reasonable to assume that all improvements must begin with the abolition of the shelves. But a visit to the natural history museum in Malmö, Sweden, convinced the writer that this is not necessarily true. The newly reinstalled systematic collection of Swedish birds actually presents itself in very attractive perspectives to the entering visitors. Abundant light, ample space between, above, and beside the cases, extreme simplicity of architectural forms and accessories such as the light fixtures, and that indefinable element that we can only call good taste in the selection and spacing of the specimens give the entire hall a pleasantly relaxed and inviting atmosphere instead of the claustrophobic tensions of our older systematic catacombs. Another acceptable use of shelves is shown by some of the exhibits of birds in the Boston Museum of Science, where vertical segmentation of the area of display is avoided through not having the shelves extend across the width of the case. In most cases, however, the museums have sought a greater freedom of display by doing away with all use of shelves.

Figure 6, from a recent installation in the Narodni Museum in Prague, gives a very fine example of the pleasing effects that can be obtained by shelf-less arrangements in space, even without the abolition of old-fashioned bases and other traditional forms of support for the individual specimens. A more frequently observed fashion in modern systematic exhibition no longer treats the supporting elements as attributes of the specimens, but rather tries to make the props part of the background design. Natural branches with their covering bark give way to wooden pegs painted to match the color of the wall from which they project. Separate base plaques of distinctive color and texture are abandoned, and the specimens are placed directly upon supporting forms that are integral

Fig. 5. Birds of Massachusetts in the Museum of Science in Boston.

Fig. 6. Bird arrangements in the Narodni Museum, Prague.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

parts of the over-all design. Figure 7 shows that good effects can be achieved by arrangement alone, even with mammals, at least when they belong to a family of reasonably limited range in size.

In a different genre, Figure 8 illustrates how even a local identification collection using more study skins than mounted specimens can be made attractive by a pleasing disposition of the material. Figures 9 and 10 illustrate arrangements of fully mounted birds in the new installations in the British Museum and also show what became of the T-perch (Fig. 9) and of the flat wooden base (Fig. 10) when shelves were discarded. Figures 11 and 12 show similar arrangements in the Hall of the Biology of Birds in The American Museum of Natural History.

A comparison between Figures 10 and 11 also brings out a point that has often forced itself very strongly upon the writer's attention, namely, the danger of using curved, and particularly symmetrically curved, shapes in the presentation of individual specimens. Such forms make it very difficult to integrate the parts of an exhibit into a harmonious whole, at the same time as they have a tendency to impress themselves far more strongly upon the attention and memory of the observer than do polygonal, and particularly rectangular polygonal, forms, of various sizes and proportions, when used together to create a setting for individual specimens. The use of curved shapes so easily tends to overwhelm the actual contents of an exhibit, with the visitor carrying away only a memory of the "artistic" arrangement itself rather than what the exhibit was intended to teach. The samples here compared are neither the worst of one, nor the best of the other, but the difference is probably adequate to illustrate the point here considered.

The modernization of the bird exhibits in the Chicago Natural History Museum is of great interest. Perhaps because the museum is younger than nearly all the other large museums of its kind, the ornithological exhibits never suffered under the regime of the shelves. Being among the first to install shelf-less systematic exhibits, the Chicago Museum was also among the first to learn that when the pattern created by the shelves is abandoned, however dreary and depressing it may be, it becomes necessary to seek other means of demarcation and arrangement to avoid the danger of a homogenized uniformity of free-floating specimens even more

Fig. 7. Systematic display of dogs of the world in the United States National Museum.

Fig. 8. Identification exhibit of New York birds in The American Museum of Natural History.

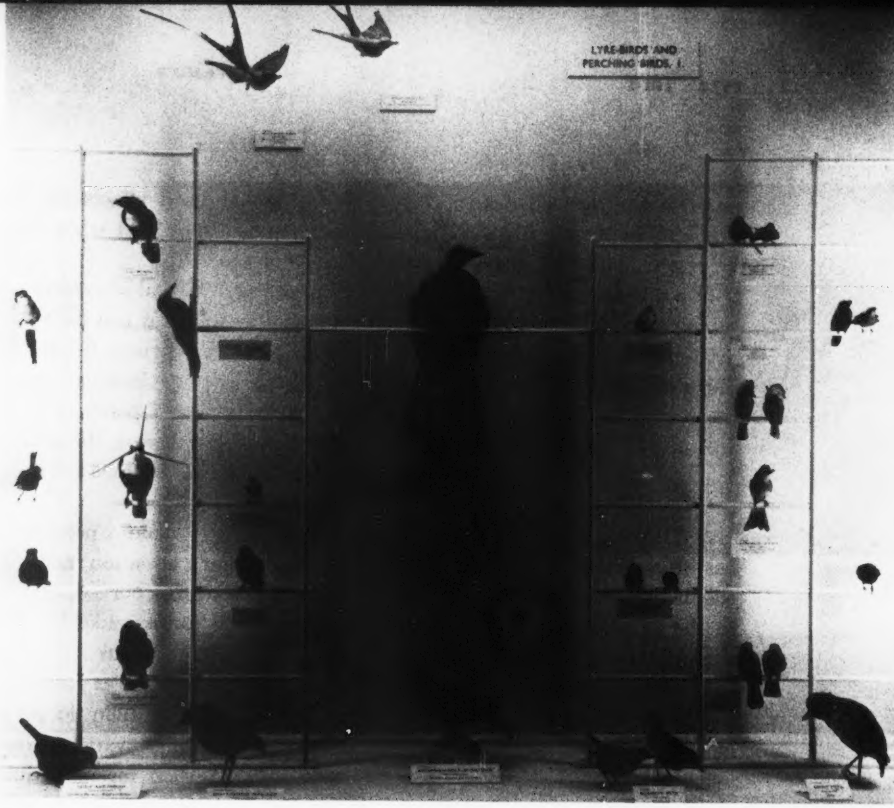
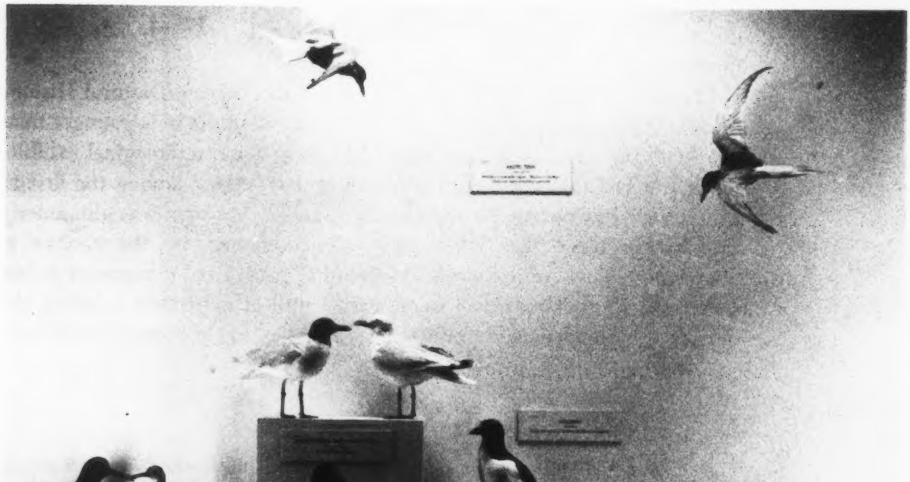


Fig. 9

Fig. 10



monotonous than their regimentation on shelves. Figure 13 gives an example of the old exhibits, while Figure 14 shows some of the new displays. Two things should be noted in Figure 14. It shows a great variety of supporting forms, including round pegs and flat plaques variously shaped and oriented, and designed to appear as extensions of the background rather than separate elements appended to it along with the specimens. Secondly, Figure 14 shows a very effective use of background panels to reveal, in an esthetically pleasing manner, systematic dis-

continued on page 130

Fig. 11

Fig. 12

Fig. 9. Lyre birds and perching birds in the British Museum (Natural History).

Fig. 10. Systematic display of jacanas, waders, and plovers in the British Museum (Natural History).

Fig. 11. Cormorants and others in The American Museum of Natural History.

Fig. 12. Turacos and cuckoos in The American Museum of Natural History.

Fig. 13. Old bird exhibit in the Chicago Natural History Museum.

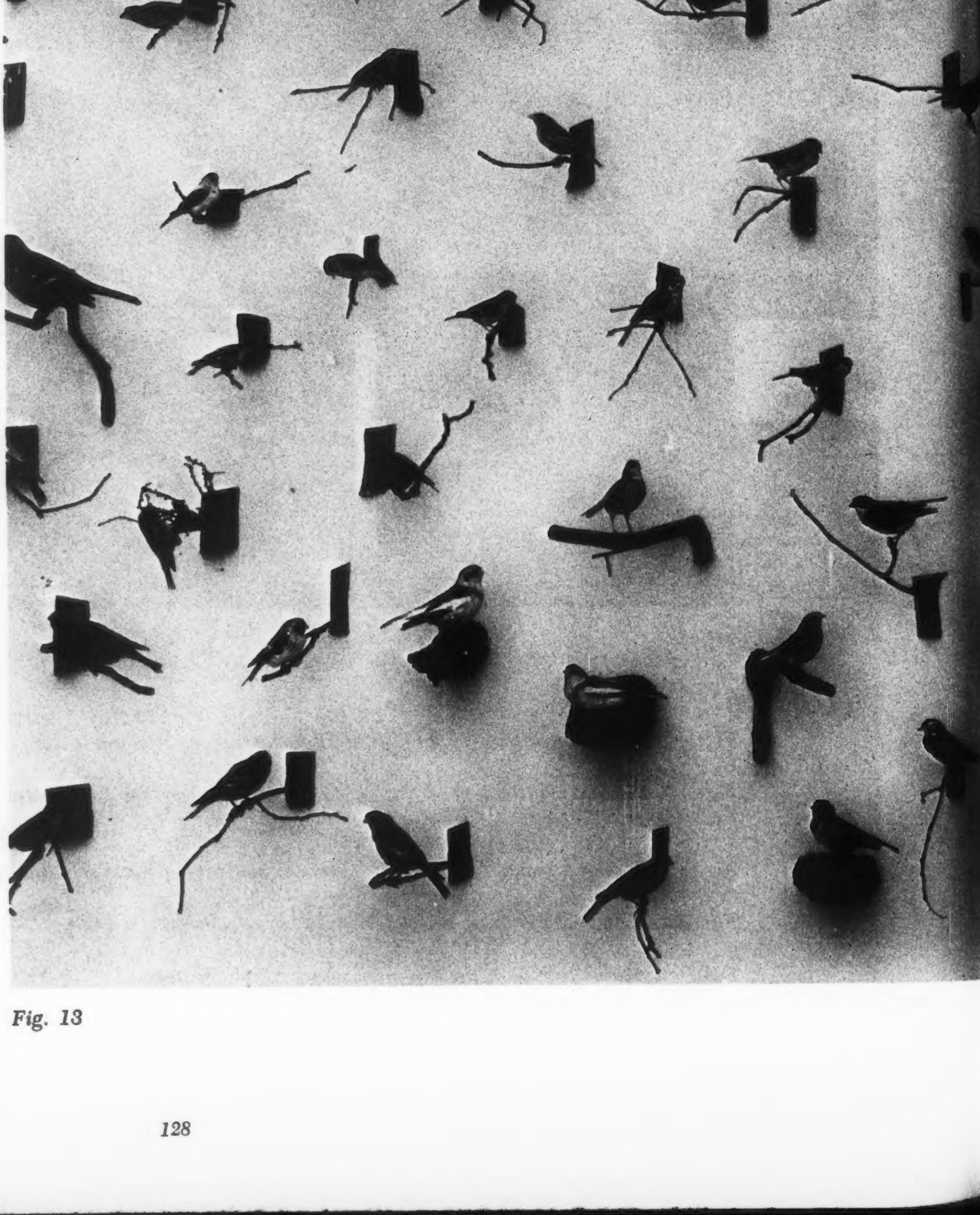
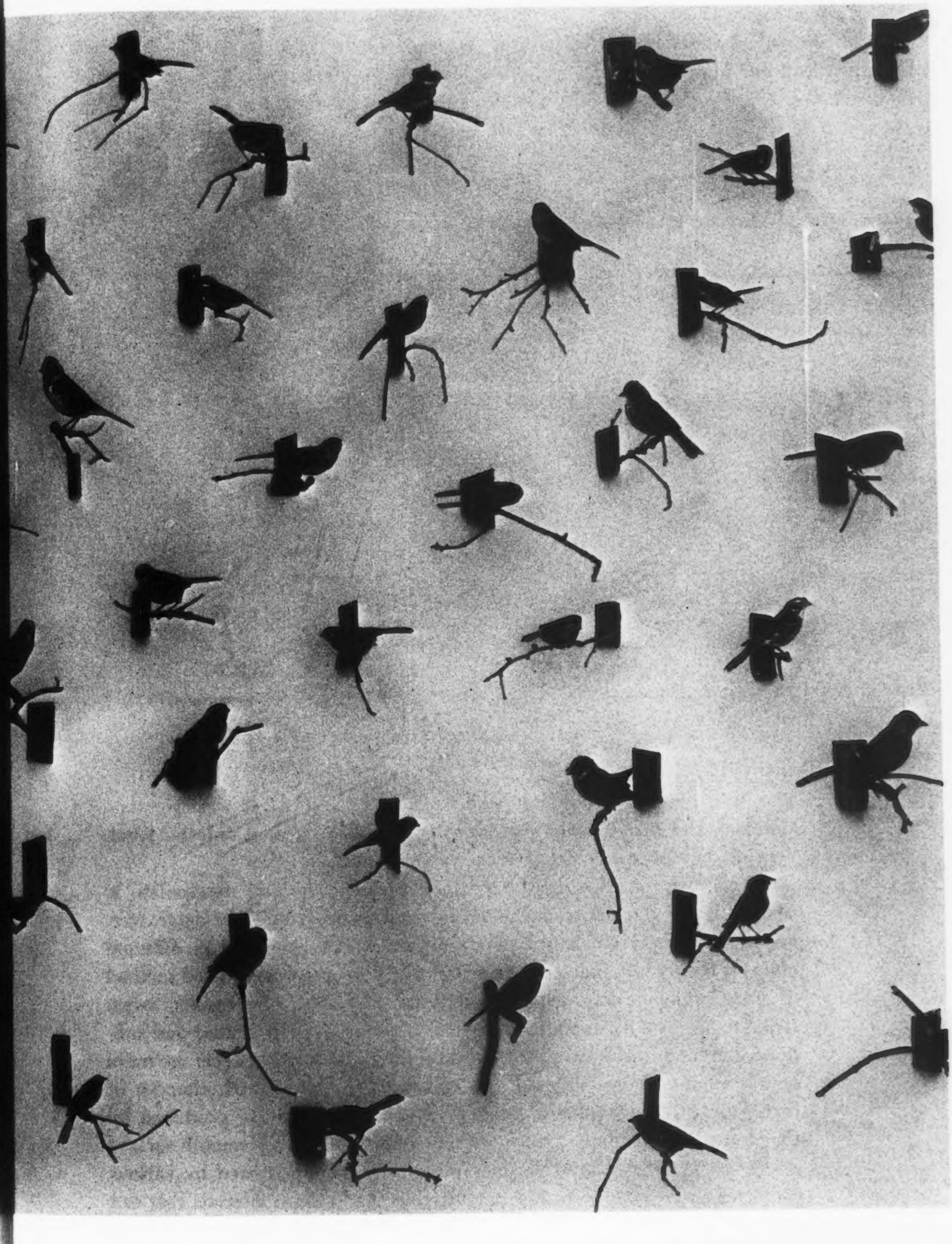


Fig. 13



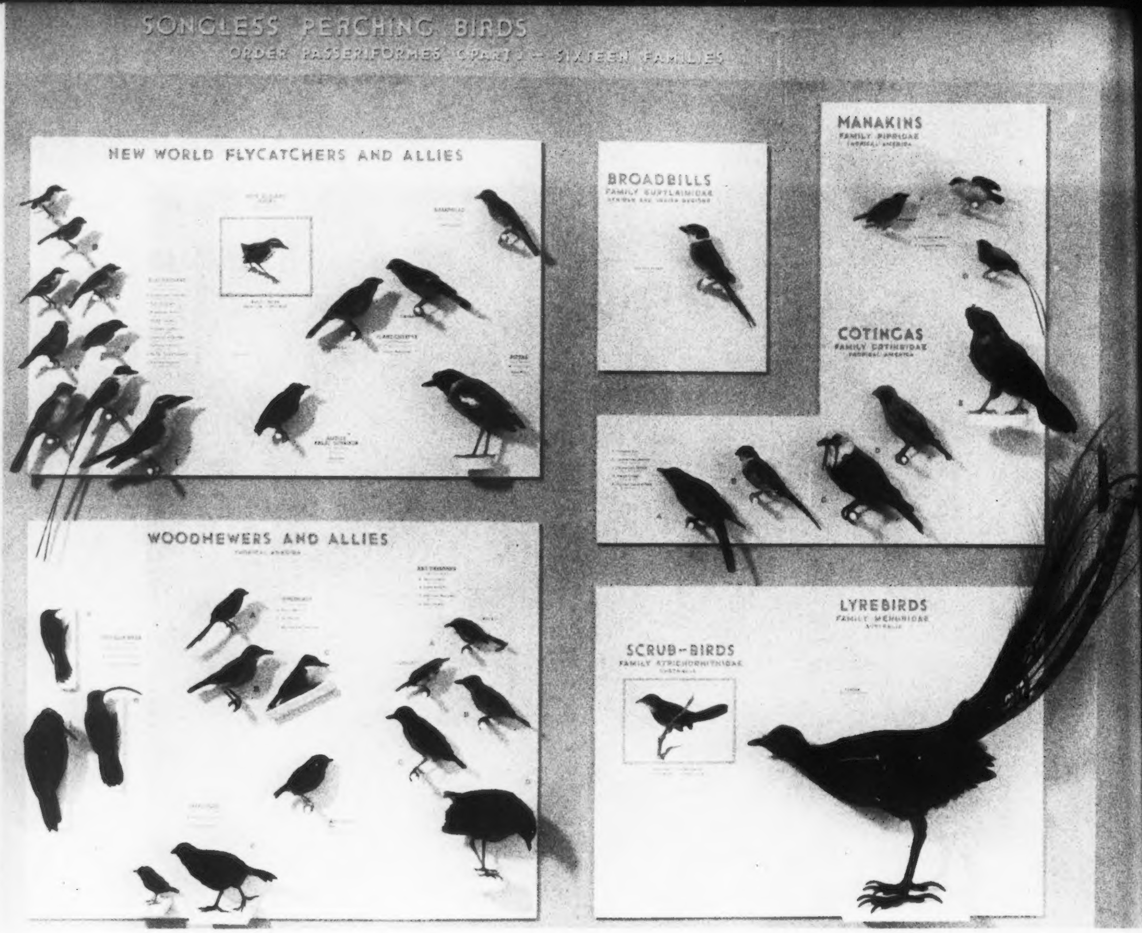


Fig. 14

tinctions and relationships that were previously indicated only by labels and proximities or distances between specimens.

Actually the display artist has three variables he can manipulate to obtain a desired effect from the background alone, namely, color, texture, and form. Simply painting various areas of the background in different colors is the easiest, oldest, and perhaps still the most widely used method of introducing variety with a significant meaning. The results, when striking, are usually unattractive; when pleasing, usually muted and subdued, although there are exceptions of both kinds. Better effects are more readily obtained when changes in color are combined with changes of texture or of form, or both. Changes in texture alone are produced by the methods of the paperhanger, as, for example, when the smooth surface of a composition board is partly exposed and partly covered by various pieces of coarse-fibered textile, smooth felts, and other materials that can

be glued on to create different surface effects. Changes in background texture without changes in form are most successful in the display of quite small objects. When we speak of the form of the background, we are thinking in the dimensions of the bas-relief, not of the free-standing sculpture, and mostly of the application to each other of overlapping

Fig. 14. From the new bird exhibits in the Chicago Natural History Museum.

Fig. 15. Grebes and loons in The American Museum of Natural History.

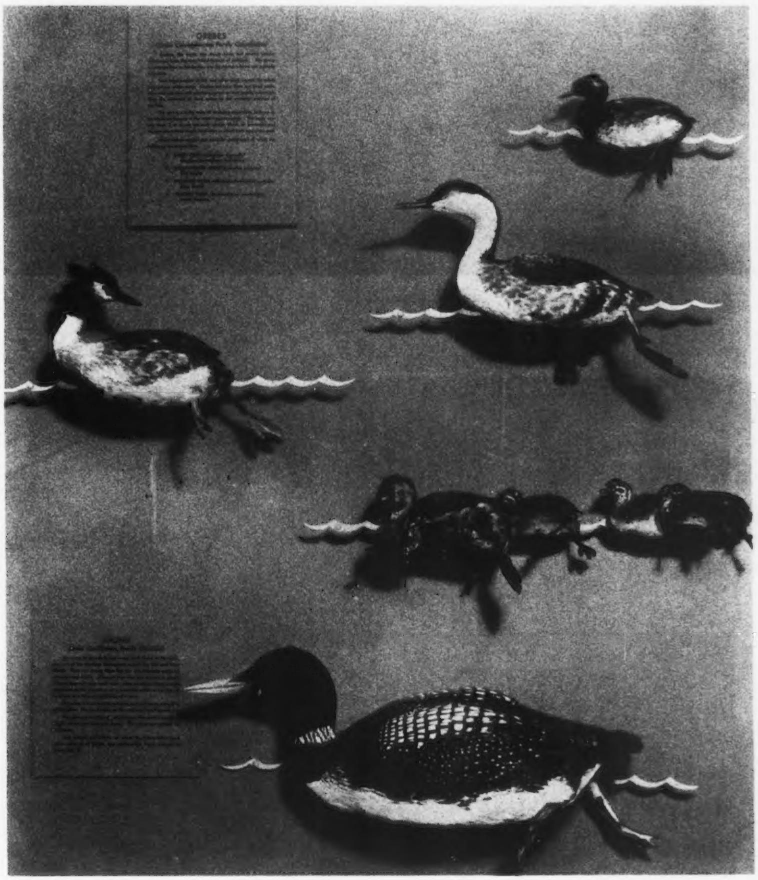


Fig. 15

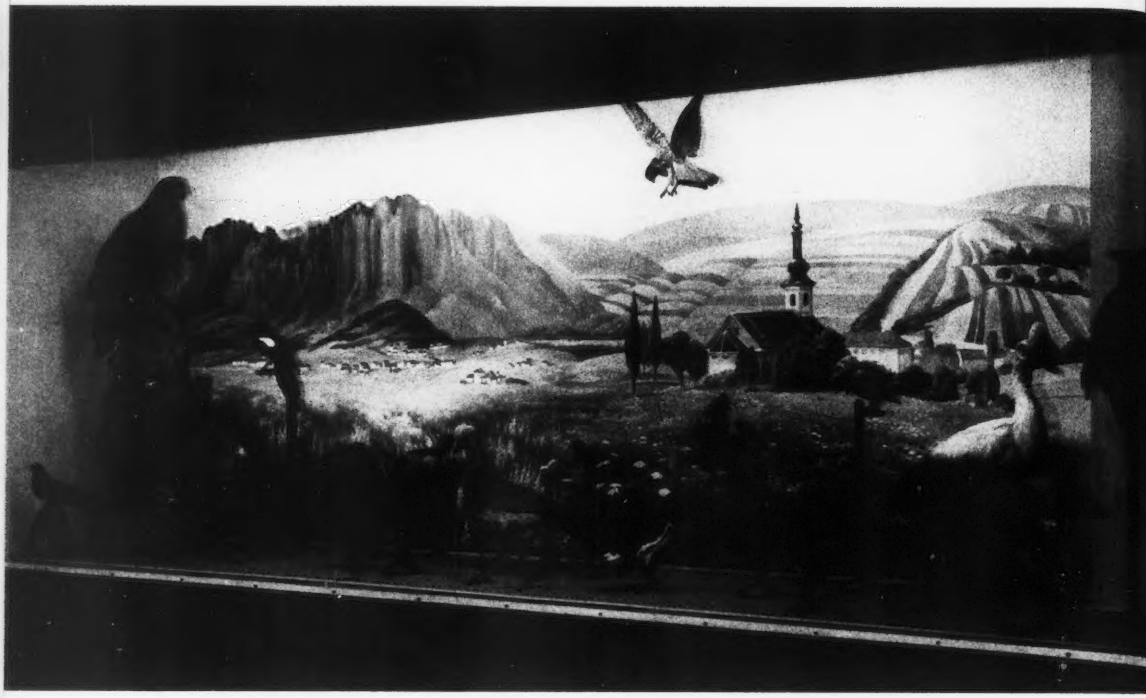


Fig. 16

Fig. 17

shapes cut from materials of visually significant thickness, so that the background is quite conspicuously divided into various surfaces falling into different vertical planes. This is probably the most effective way of making the background contribute both to the contents and the esthetic variety of systematic exhibits. Other methods include the application of colored wires or other narrow forms to replace mere lines simply and undramatically painted directly on the background surface.

The reaction against shelves often seems to have resulted in an overanxiety to conceal the vulgar need of mechanical support for the specimens, either by actually hiding the supporting device, or so integrating it with the architectural framework of the exhibit (see Figs. 8, 12, and 14) that it seems part of the container, rather than something pertaining to the needs of the specimens. But this de-emphasis of the practical necessities does not represent the only direction in which happy solutions can be found. It is also possible to emphasize the mechanical supports to very good effect, as shown, for example, by the trellis-like contraption (see Fig.

Fig. 16. Birds of Spain in the Academy of Natural Sciences of Philadelphia.

Fig. 17. Ducks in the Academy of Natural Sciences of Philadelphia.

Fig. 18. Giant fossil crocodile skull in the American Museum.

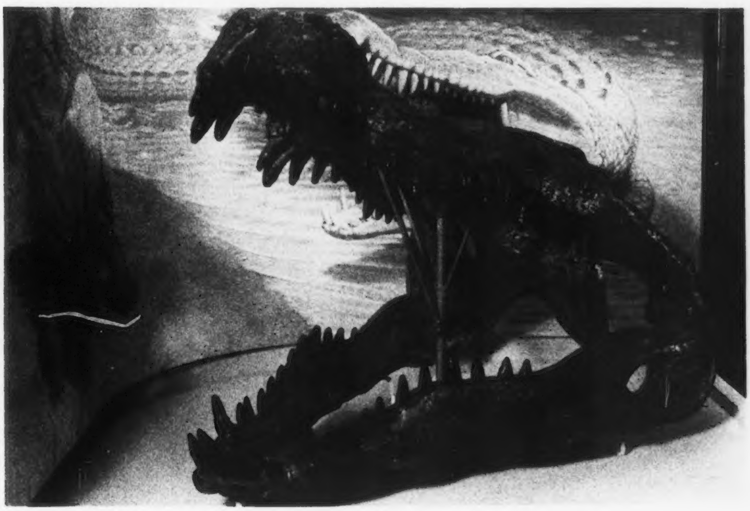


Fig. 18

9) used to advantage in the new hall of birds in the British Museum (Natural History).

All the improvements and embellishments discussed up to this point are purely formal and esthetic, serving only to make more palatable the contents already present in the oldest systematic exhibits on their crowded shelves. Giving the decorative treatment its own message to convey provides opportunity for a still richer variety of presentations.

An extremely simple example of a pleasantly light touch is the small ornamental waves indicating both the aquatic environment and the Plimsoll lines of the grebes and loons shown in Figure 15. A far more elaborate

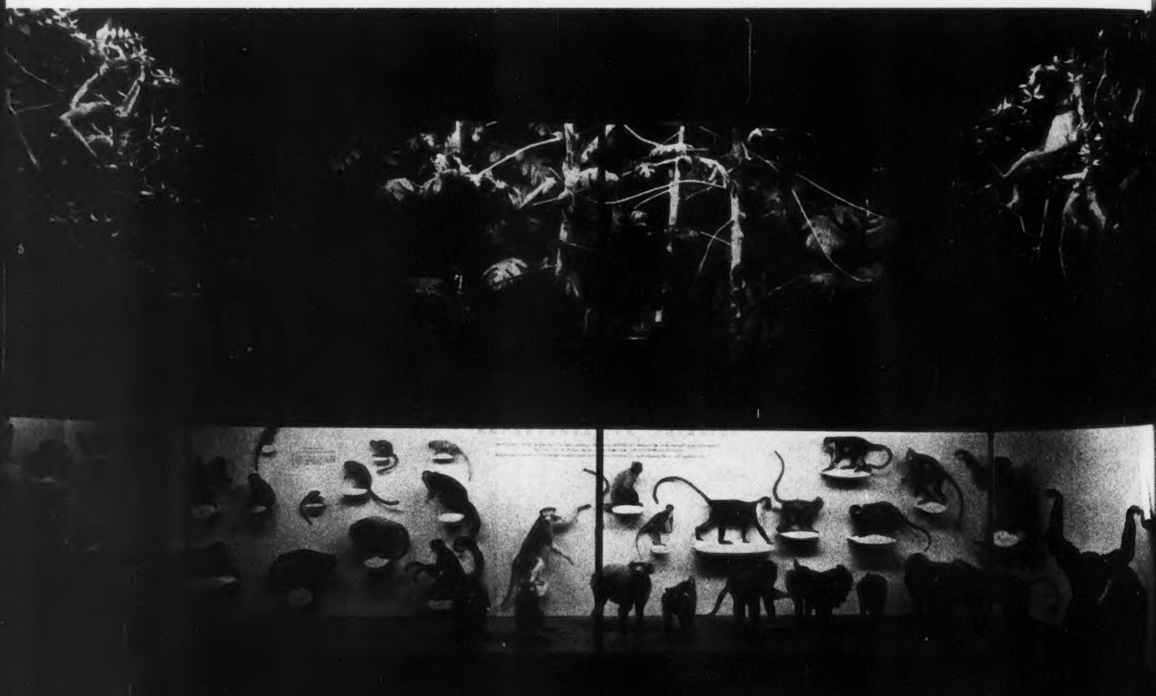


Fig. 19

Fig. 20

and lyrical addition to the display of separate specimens in geographic systematic order is presented by the background paintings used in the Academy of Natural Sciences of Philadelphia behind specimens often boldly poised on unadorned T-perches varying only in height. Each painting covers the entire rear of a case with a type of landscape that has come to be regarded as representative or symbolic of the region covered by the exhibits shown in front. The style of painting appears to this writer, at least, to have strongly romantic overtones which do not seem out of place, and the total effect is both very unusual and very enjoyable.

The distinction between the systematic exhibits in Philadelphia and

Fig. 19. New primate exhibit in the United States National Museum.

Fig. 20. Old primate display in the United States National Museum, photographed about 1925.

those that the author on a previous occasion[2] has referred to as pseudo-habitats may seem slight but is nevertheless real. In the pseudo-habitat there is a pretense that the specimens actually have invaded an abstract environment and occupy natural positions on, or among, its conventionalized forms. In Philadelphia the specimens themselves are simply placed on traditional stands, frankly divorcing them from the painting behind.

The use of a pictorial reconstruction of the beast painted in very subdued colors behind a giant fossil crocodile skull in The American Museum of Natural History may perhaps be regarded as a method distantly related to the technique employed in the Audubon Hall in Philadelphia.

In the new mammal exhibits in the United States National Museum, habitat groups overhead have been used in a very striking and effective manner to enrich a systematic display of primates, at eye level. Comparison with an old installation of corresponding material in the same institution (Fig. 20) bears amusing testimony to the progress of our ideas about systematic display. One must regret that the particular combination used in Washington can lend itself only to the presentation of arboreal or aerial life, but it might well find a wide application in ornithology.

In the Zoological Museum in Bergen, Norway, the formal approach to the art of display has given way to casual and intimate informality. Nonobjective architectural or decorative motifs are entirely lacking. Instead, the exhibit is enlivened by the use of anecdotal items to provide the necessary support for the specimens in a pleasing over-all arrangement. The material does not pretend to have the contents of habitat groups, but by reminding of incidents of common occurrence, and particularly incidents involving man and his works, the accessories serve to establish an association between the specimens and the visitor's own experience that cannot avoid stimulating his interest. One notes a wagtail on the grip of a shovel, sparrows in a sheaf of grain such as is customarily hung out for the birds at Christmas, swifts on telephone lines with pole and porcelain insulators, a thrush on the gilded spear at the top of a flagpole, man-made bird houses, and a parenthetic suggestion conveyed by a broken piece of barbed wire. This "humanizing" of a museum's exhibits has much to recommend it, and when we consider that Figures 3 and 21 deal with the same subjects in the same museum before and after modernization, we may get a measure of the extent of the revival of systematic exhibition at its best.

[2] Parr in CURATOR, vol. II, No. 2, p. 125, figs. 20 and 21, 1959.

Fig. 21. Glimpses from the new systematic exhibits of birds in the Museum of Bergen, Norway.

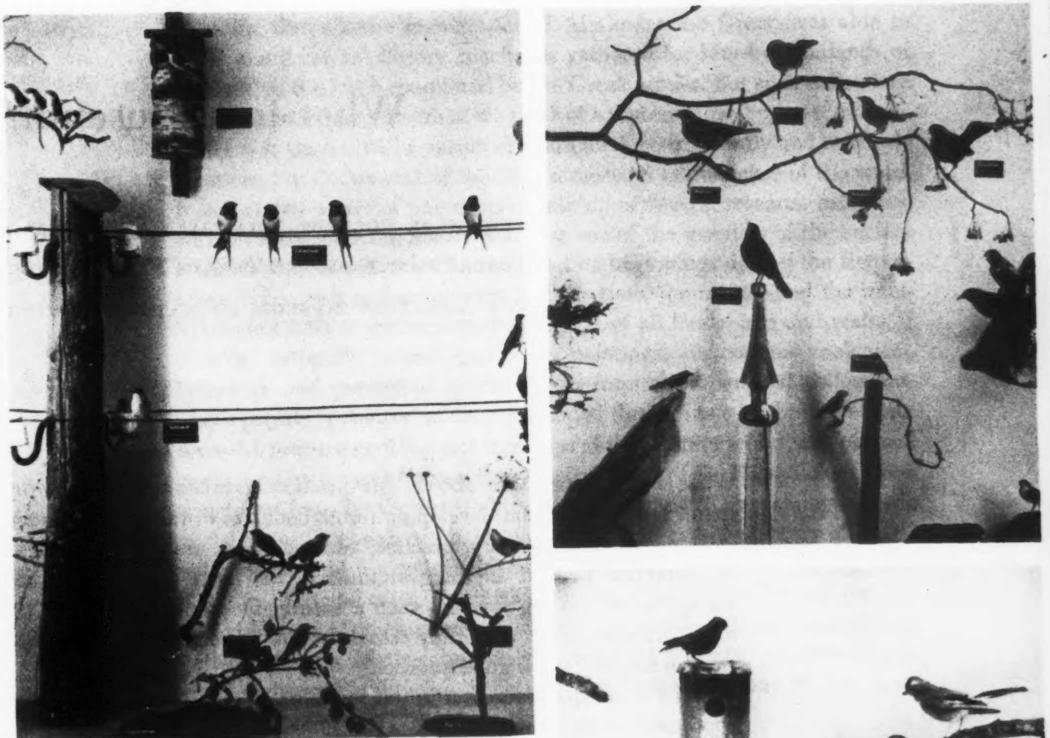


Fig. 21

What is a Museum?[1]

EDWIN H. COLBERT, CHAIRMAN AND CURATOR
DEPARTMENT OF VERTEBRATE PALEONTOLOGY
THE AMERICAN MUSEUM OF NATURAL HISTORY

What is a museum? Why should this question be asked today, when museums are growing and developing throughout the world as never before and when museum theory, practice, and technique are reaching heights of perfection beyond anything attained in the past? Does it not seem strange to be putting forward such a seemingly simple question at this time, when museums are firmly established in the culture patterns of all modern nations? Is it a good question?

It is a good question even in our modern age, because today there is apparently much confusion as to what a museum is or what it should be. In spite of the spectacular growth of museums in numbers and facilities, and in spite of the augmentation of museum personnel within the past few decades, much misunderstanding still remains as to the functions of a museum in our present world. Indeed, instances are common in which the misunderstanding, or perhaps the misinterpretation, of what a museum should be and what it should do is so deep-seated within the minds of those who are directly concerned with the institution that its functions and the role it should play within the community are grossly violated. Therefore it is pertinent to take a good look at the museum and to try to evaluate it.

As a prelude to this review it may be useful to make a very brief excursion into the historical background of the museum as we know it, and to say first of all that such an institution was unknown in the ancient world. There were collections of paintings and statuary in temples and in the homes of wealthy patricians, and some men with inquiring minds collected objects of various sorts from the far corners of the known world.

[1]Keynote address delivered at the Seventh Mountains-Plains Museum Conference, Santa Fe, New Mexico, September 15, 1960.

Aristotle, through the munificence of Alexander the Great, was able to study many natural history specimens gathered for him by thousands of men within the lands conquered by the Greek armies. But such collections did not repose in a museum as we think of a museum.

Nor was the original museum of Alexandria, so frequently and tediously mentioned in discussions of this sort, a museum in our sense of the word. It was rather a sort of university, made up of several research institutes, with an accompanying library that was one of the wonders of the ancient world. The museum as we know it had its beginnings during the Renaissance, when rich and noble men had the time, the means, and the intellectual curiosity to gather together objects of all kinds—arts and crafts of classical antiquity, medals and coins, paintings, and various zoological, botanical, and geological specimens—to form their personal collections. These private "cabinets" as they developed through two or three centuries were the precursors of the first museums of the western world, and of them perhaps none is more famous than the collection of Sir Hans Sloane, upon which was founded the British Museum. According to the catalogue made at the time of Sloane's death, his collection consisted of a library of 30,000 volumes, natural history specimens to the number of about 45,000, some 32,000 medals and coins, about 2000 objects of antiquity, 310 pictures, and 55 mathematical instruments. Such was the scope of things brought together during a lifetime by one gentleman of the late seventeenth and early eighteenth centuries. Such was the heritage of one of our great modern museums.

It is well to keep the heritage in mind, because from it our modern museum has grown as a place for the safekeeping of things. This, it seems to me, is one of the two primary functions of the museum, an institution founded as a repository for the preservation of *objects*.

But a repository in which objects are stored away for safe keeping is little more than a warehouse. Consequently the modern museum has a correlative primary function—that of *interpreting* the objects entrusted to its care, of making them significant to mankind. Interpretation of museum objects is done in two ways, either by *research* or by *display*. Research is basic; the object remains a potential rather than a really significant thing until something is known about it. Display grows out of possession of the object and the research done on it. Many museums interpret their objects both through research and display; some, only through the one or the other of these functions. But in the opinion of the present writer, unless an institution has objects in its possession, which it interprets through research or display or both, it is not properly a museum. Various organizations across the land today call themselves "museums" which do not fulfill the basic museum functions as outlined above.

In the light of these remarks, let us now turn to some consideration of

the museum as a repository, as a research institute, and as an exhibition place.

The collections are the first reason for the museum's existence. Here are the things of the world maintained for the present and for the foreseeable future of mankind, a record that becomes ever more valuable and frequently unique as the years pass by. These objects retained within the walls of the museum building in themselves make the museum an institution different from any other; they make it a *museum*—not a library, nor a university, nor a display center. Because of the central importance of objects in the museum, it is crucial that much careful thought should be given to the kinds of objects to be contained within the collections, how they are to be preserved and cared for, and how they are to be kept. These are not routine considerations.

One of the great problems bearing on the repository function of the museum is that of acquisition. What should any particular museum have in its collections? This depends on the scope of the museum, determined by its primary nature and by its secondary limitations. As for the primary nature of the museum, its function as a museum of natural history, or of anthropology, or of history, or of art, or of some other subject will necessarily determine the general content of its collections. Yet this is not enough to define the boundaries of museum collections, because no museum, no matter how large and no matter what its resources, is able to encompass completely the field in which it operates. Thus it must limit itself in some secondary manner, such as by geographical areas, or by political boundaries, or by imposed limitations within the subjects that concern it, or by specializations, and the like. If a natural history museum regards the entire world as its field, it may very likely not include all phases of natural history. If it is limited to a nation or to some national subdivision, it can perhaps be completely comprehensive within such limits. The museum of an historical society may be limited not only geographically but perhaps temporally as well. Also, art museums are commonly limited by their subject matter.

That a museum determine the limits of its collections, that it establish a policy of acquisition, and that it hold to this policy through thick and thin are of supreme importance. Such considerations seem self evident and axiomatic, yet the shoals of opportunism have caused the foundering of many a museum. It is tempting for the institution to acquire things that come easily; considerable will power and fortitude are required to turn down a magnificent collection or the opportunity to make a large collection, when the collection or the opportunity are only slightly out of line with the avowed limits of the museum. Yet unless the museum holds rather firmly to its policy of acquisition, determined by the nature and the limitations of the institution, it is in grave danger of diffusing its resources

and ending as an organization without any clear purpose for being.

Going hand in hand with acquisition are the duties of preservation and storage. Consequently it is necessary for the museum to maintain personnel and facilities that will insure the proper care of the collections housed within its walls, and the necessary space for the keeping of the collections. Otherwise the institution is not living up to its obligations.

Such are a few basic considerations having to do with the primary function of the museum as a repository. What about the correlative primary function—as an organization for the interpretation of the objects entrusted to its care? With the passage of the years, this function of interpretation has become of increasing importance in the program of the museum. It makes the modern museum a vital organization and a lively place; it removes the stigma of dusty inactivity from the museum, a stereotype that is still all too common in the mind of the general public. Today it is of equal importance with the safekeeping of objects for justifying the existence of the museum in modern society.

Interpretation through research is fundamental. Consequently, a first-class museum is, among other things, a research institution. Here the objects within the museum are studied and, through such study, become significant to the scholar, to the student, and to the general visitor. It should be added, however, that the significance of museum objects does not come from research alone, but rests to a large degree on the publication of that research. Only when the results of studies are described and illustrated on the printed page do they become meaningful to the world of scholarship and to the world at large. Until publication, research has a value only in being, a potential value that has as yet not been truly consummated. Therefore the museum as a research institute is also a fountainhead of publication, a source of original and valuable studies in which meaning is given to the objects that make up the collections. In the long view publications are perhaps the most enduring things about the museum. Ancient Rome is in ruins, but the writings of Caesar and of other great Romans live on. Likewise the publications that describe collections probably will be available to future generations long after buildings have decayed and collections have disappeared. Nothing is quite so enduring as the written word.

These remarks point up an important fact concerning museum research, namely, that such research is based primarily on the objects in the museum collections. This statement should not be interpreted as a justification for narrow studies confined to the objects at hand. Our concept of museum research today is much broader than the old idea of descriptive catalogues, so that studies carried on under the authority of the museum may range far afield, frequently to penetrate areas of knowledge and to use scholarly techniques far removed from the purlieu of the

catalogue and the storage shelf. Such studies may in a sense be peripheral, yet so long as they throw added light of knowledge on the objects within the museum, and what these objects represent, they are properly within the confines of museum research. Thus a zoologist may go out from a natural history museum to spend a summer making recordings of bird songs; a student of fossils may spend a season investigating the relationships between the temperature of sea water to the growth of corals; or a curator in an art museum may be concerned with the subject of Buddhism at Angkor Wat. Although these activities have no direct connections with collections, they nonetheless add dimensions to the interpretation of objects within the museum walls.

As has been said, research is the basic interpretive function of the museum, and for a few museums it is the only function of interpretation. In other words a museum can be an excellent institution of its kind without ever attempting a program of exhibition, a fact that frequently is not appreciated by people outside, or even within, the museum profession. The well-balanced museum has, however, an exhibition program in addition to its research program of interpretation, while for many museums display is the only type of interpretation carried on. Research for these latter is too difficult and too expensive an activity to be attempted.

It should be realized that exhibition is always a secondary mode of interpretation, for it grows out of research. If the museum has no research program of its own, it must of necessity lean upon other institutions, which do carry on basic research in their particular fields, as the foundation for its exhibit activities. Here again we have a source for much misunderstanding of the true functions of the museum. All too many people, particularly the non-articulate public, but also, sadly enough, numerous writers and critics, think of the museum only in terms of its display activities. They fail to appreciate the fact that a good museum, like an iceberg, is to a large degree not discernible to the casual eye, and thus they base their judgments of the museum's worth on activities that have to do with only a fraction of the museum's function and resources.

Such judgments may not be entirely fair, but the reaction is natural, because the exhibit hall is the link between the museum and the community. How indeed are persons outside the museum profession to judge the museum except through what they see in the displays? Here are placed the best and the most characteristic things that the collections contain, and if they are exhibited in a meaningful fashion the museum is then performing an important service to the public, a service that finds its reward in the wide and general appreciation on the part of the public for what the museum has to offer. In this day there is little reason for a museum man to expect a cloistered life. He and his institution can and should play a lively part in the community they serve, and in return they

can expect loyal support from that community. The best stimulus for such support is an active and well-planned program of exhibition, by means of which the museum not only fulfills its obligation to the community but also convinces the community that it is a worth-while organization, fully deserving public support. Nothing succeeds like success, and it is no accident that the most sucessful museums are those that devote much attention and energy to the development of their exhibits.

Exhibits in the museum are particularly important because of their contribution to education. One facet of the interpretive function of the museum is its educational activities, integrated with the programs of various educational institutions of the region served by the museum. Good exhibit halls serve not only the individual museum visitor, but also school, high school, and college classes that come to the museum to view graphic displays of original three-dimensional objects described and illustrated on the two dimensions of the printed page.

This closes the circle, one might say, of basic museum functions. The curious visitor and the serious student come to the museum halls to see the objects displayed. The objects on display are interpreted through research that has been done upon them. All the objects in the museum, not only the objects visible to the wanderer through exhibition halls but many more safely kept in the storage rooms, are here preserved against the ravages of time. To the question of what a museum should be, here is the answer.

In theory it is the answer. In practice it is not the complete answer, because as yet nothing has been said about museum men. The eternal truth that no organization is any better than the men who comprise it is all too frequently forgotten in the museum world, just as in other fields of human endeavor. Yet this fact can never be ignored, if the functions of the museum are to be carried on properly and to good effect. Good men make good museums.

The heart of the museum is the staff, and the vitality of the museum depends to a large degree on the devotion and the activity of this group of people. Indeed, many a museum owes much of its success to the dedication of some, if not of all, of the people who make up its staff, people who work intensively and often live almost selflessly in the service of the museum. This is not to be wondered at, because for a majority of professional museum people museum work is more than a job, it is a career and a way of life. Serious inequities in the museum world have been a result.

Most museum professionals are sadly underpaid. For people to whom the museum is a career and a way of life, there is nothing else to take its place; consequently these folk will work in a museum at low salaries rather than shift to more remunerative ways of making a living. The institution that is trying to stretch its resources very frequently takes ad-

vantage of this fact, whether it wishes to or not, and the deplorable situation continues through the years. One sees this graphically displayed in university museums, in which the museum staff commonly is on a salary scale that fails to measure up to the salary scale of the academic staff. One of the goals most ardently to be sought after in the museum world is proper salaries for museum employees. Only in a few institutions, and sporadically, has the goal been achieved.

But money is not the alpha and omega of life, especially to museum men, so there are other very important desiderata for making life more pleasant and work more efficient in the museum world. One of these, and a very important one, too, is freedom from undue interference. This means interference from within and from without—from the administration of the museum and from the public. Most museum men are doing creative work of one sort or another, and for them there must be time available in which they can think their own thoughts or carry on their special activities. It was said above that the museum man cannot expect to lead a cloistered life, which is true. On the other hand, he should not be constantly subjected to the pressures and distractions that seem so typical of this age. Creative thinking and creative achievement require some degree of tranquillity, which the museum should provide, if it expects to use to good advantage the talents of its men. In museums that carry on research programs, the right to do research is thereby implied—research that follows the peculiar bent of the man who is doing it, research that is free from the trammels of expediency. Only through such research can the objects that repose within the museum be properly studied and interpreted.

These remarks are concerned with what might be considered as the prerogatives of museum staff members. There are requirements also, and of these perhaps the most important are high professional standards and thorough training. Museums need to eliminate the amateurism that has in the past been so widely characteristic of many museum practitioners. The situation is happily improving through the years, but even today too many people drift into professional museum careers without the proper foundations on which to build their activities. It is necessary to define more clearly than has been done the standards of the museum profession.

Mention of the museum profession raises another point, namely, that some sort of professional status should be established, in a field that in a sense is without a unifying force except that of the museum itself. What does an entomologist working on beetles in a natural history museum have in common with an authority on prints in an art museum? Very little, except that both men are museum men and should be held together by the museum tie, just as professors throughout the land are united through their university connections. Much advancement remains to be achieved in this important aspect of human relationships within the museum. It would be

helpful to the entire museum world if, in this country, museum staff members could establish for themselves something akin to the American Association of University Professors.

This discussion of the museum staff has not as yet made mention of the museum director. His is a special position—in part a member of the staff, in part somewhat separated from the staff. He is, in truth, the link between staff and trustees and thus occupies a crucial position. A good director directs, which can be most helpful and stimulating to the staff with which he works, but he should not domineer. He translates policies into action, and in so doing he should exert himself with much understanding of the human animal, for museum staff members are very real people despite their dedication, and trustees are also very real people despite their positions within and outside of the museum. The director should be a good administrator, yet he should be a scholar, familiar with some field included within the bounds of his museum's program. Only the director who is a professional museum man can appreciate fully the functions of the museum and the proper way in which these functions should be performed. So it would appear that the director must be a paragon of many virtues, which frequently he is not.

The other museum men are the trustees or overseers. It is no secret that, generally speaking, the constitution of boards of trustees of educational and cultural institutions in North America often leaves much to be desired. Many trustees are well chosen for the task they are called on to perform, and they carry out their responsibilities as trustees with conscientious application and skill. Others lack understanding and fitness for their appointments. The trouble is largely in the haphazard selection of boards of trustees. In short, boards are frequently one-sided and do not represent a cross section of the community, as they should. It would have a salutary effect if many more boards than are now so constituted could have among their members, in addition to business leaders and men of political stature, eminent scientists, writers, artists, engineers, social workers, and the like. Considerable stimulation and an increased understanding of the problems that are involved could come from such heterogeneous boards, on which many aspects of human endeavor were represented.

The matter of understanding brings up another point, namely, that trustees ought to have a deeper understanding of the functions of the museum, of what the museum is for, and of what it is trying to do. An increased contact between trustees and staff members might be very desirable, particularly, as has recently been suggested, in the form of roundtable discussions between staff and trustees. This procedure, if wisely followed, should lead to marked advances in relationships and understanding in both directions, from trustees to staff and from staff to trustees.

Thus an attempt has been made to answer the original question, What

is a museum? In summary, a museum is an institution for the safekeeping of objects and for the interpretation of these objects through research and through exhibition. It is an institution depending on the efforts of the people connected with it—staff, director, and trustees—who, by working together harmoniously, can make it a truly effective and significant organization. It is an institution playing an ever-increasing role in our culture and a part of our life that we, as museum people, can be proud of. Looking forward, the future of the museum can be viewed with confidence and with the expectations of great things to come.

An Exhibit of Mollusca

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The Phylum Mollusca, with an estimated total of 80,000 to more than 100,000 described species, includes more species than any other animal phylum except the Arthropoda. From time immemorial also it has been drawn upon extensively by man for personal and other decoration, for food, and for a variety of other purposes. In their size, anatomy, and habits the mollusks show enormous variation, illustrated, for example, by the contrast between the giant, fast-moving squids, large enough to tackle a whale, and minute almost microscopic univalves such as *Rissoa.* All these facts are embodied in an abundant literature[1] and need not be further stressed here. The object of the present article is to describe an exhibit which endeavors to present to the public in a small compass some of the main facts about mollusks as animals and their importance to man.

The fact that shells (as will be obvious from the illustrations) figure very prominently in the exhibit is not considered to need any apology. Dr. Paul Bartsch of the United States National Museum wrote long ago, "The shell, in spite of what some soft anatomists would preach, is the soundest single element that one can use in the classification of Mollusca. It is comparable as far as its value for classificatory purposes is concerned to the skeleton of . . . . the vertebrates . . . . and . . . . in the molluscan skeleton, unlike that of the vertebrate, we have the story of the entire ontogeny of the animal engraved." Although the "soft anatomist" may have different views, he must at least recognize that the shell does have both a scientific value and often a great esthetic appeal, while at the same

continued on page 150

[1] A beautifully illustrated recent example is "The Scallop, Studies of a Shell and its Influences on Humankind," edited by Ian Cox and published by the Shell Transport and Trading Company, Ltd., on the occasion of their Diamond Jubilee, London, 1957.

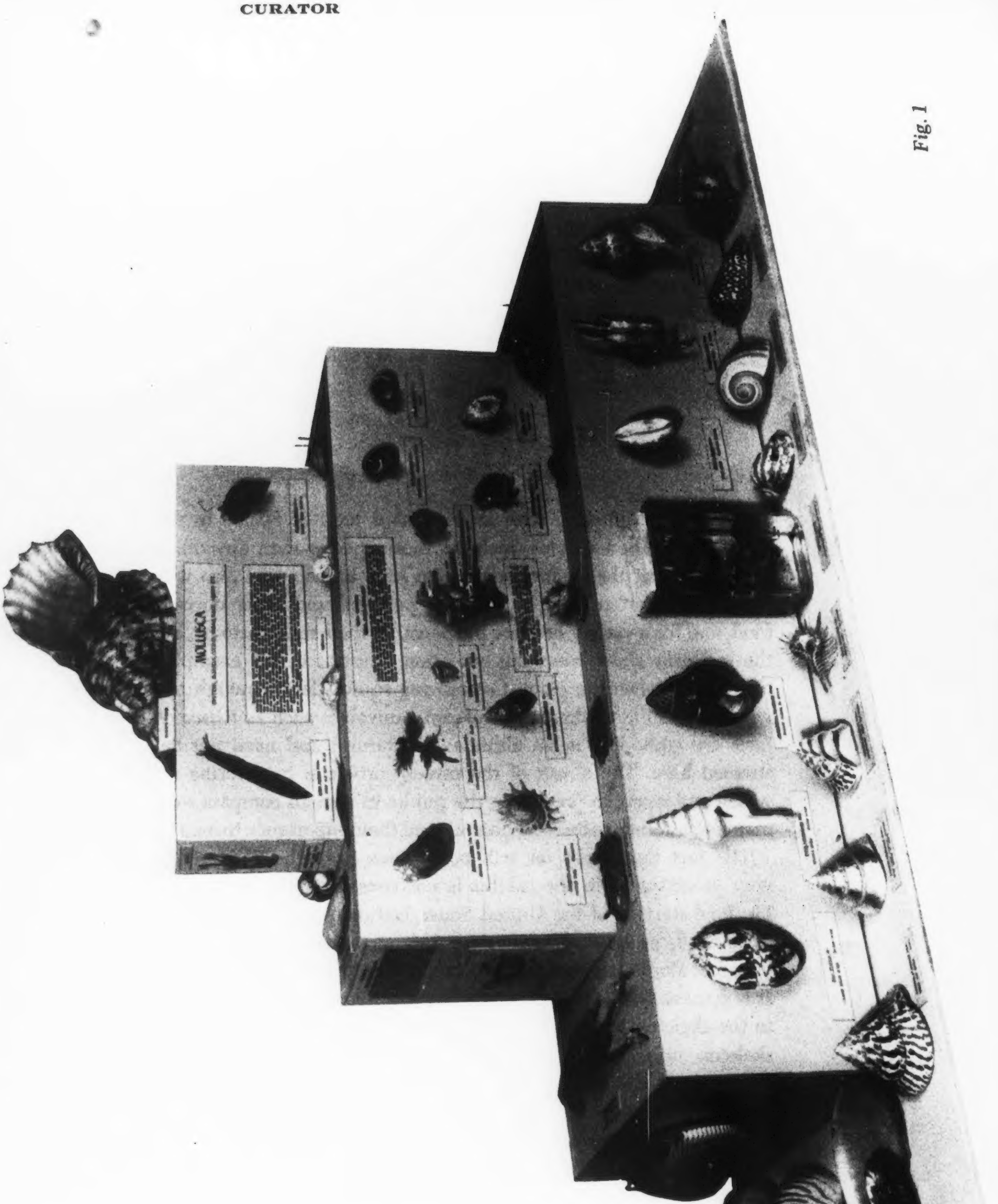

Fig. 1

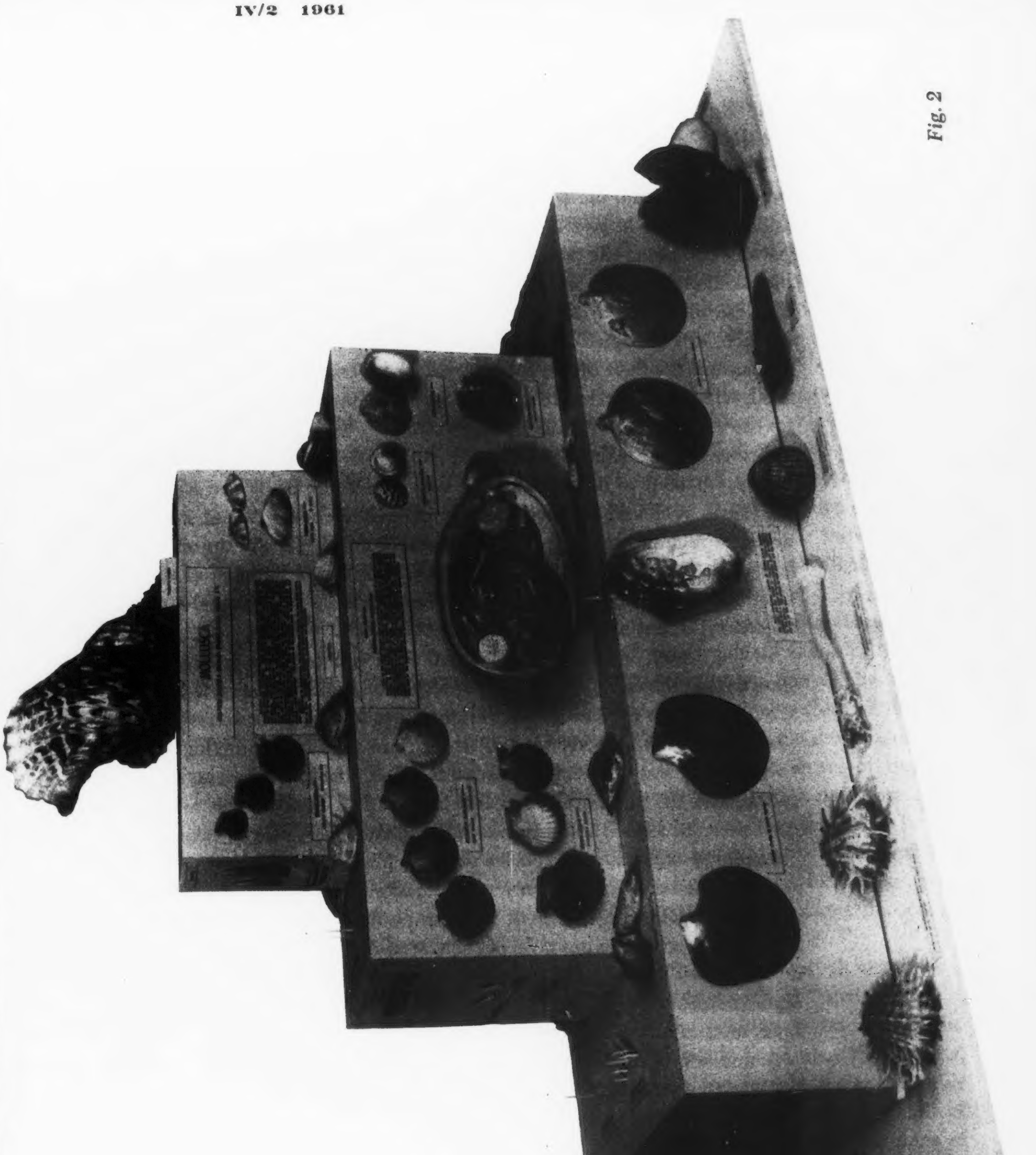

Fig. 2

time rightly rejecting the old tradition of displaying little else except the shells.

The exhibit is contained in a free-standing case of South Kensington type, with internal dimensions of approximately five feet in length by two and a half feet in width and four feet in height. It is in four tiers, the bottom one being the floor of the case, above which rise three rectangular blocks diminishing in length and width towards the top. The vertical faces of these blocks, and the horizontal shelves formed by the exposed parts of each, are occupied by shells, models, dissections, and diagrams. The blocks and the floor of the case are colored a brownish yellow, suggesting sand, which was judged to be on the whole the most suitable background for the varied types of material displayed.

Crowning the exhibit is a fine example of Triton's Trumpet (*Triton tritonis*), stated to have been used as a war trumpet by the islanders of the South Seas and by several other peoples in both ancient and recent times, as it could produce a harsh, booming note after the tip of the spire had been broken or ground off. Taxonomically it is a member of the Class Gastropoda and below it, on one side of the case, are displayed a series of species representing that class (Fig. 1).

In the center of this side, a vertical section through a gastropod shell shows what the internal structure of the shell looks like, and is labeled to show the names applied to the various parts—the spire or series of whorls (except the last or body whorl), the suture or line of junction between two whorls, the columella or central pillar, the posterior and anterior canals, and the inner and outer lips of the shell. Beneath this are labeled dissections of a male and a female of the Common Whelk of British shores (*Buccinum undatum*), a species of some importance as food. These dissections illustrate the anatomy of the body or soft parts of a gastropod and their relation to the shell. The composition of the shell itself is suggested by a complete example of the Great Top shell (*Trochus niloticus*), accompanied by another of the same species in which the outer layers have been ground away, to reveal the beautiful iridescent appearance of the inner mother-of-pearl layer.

A number of models show the animals as they appear in life and illustrate the wide variation in the size and shape of the shell relative to the body. On the face of the upper block are exhibited models of the Whelk carrying its strong heavy shell, and of the Great Gray Slug (*Limax maximus*), with the shell reduced to a mere vestige. The face of the central block carries models of some of the beautifully colored "sea slugs," such as *Glaucus* and *Doriopsis*, nudibranchs which have no shell in the adult state, as well as of other more typical gastropods such as *Murex*, *Cerithium*, and *Neptunea*. The remainder of the specimens on this side of the exhibit illustrate the great range of variation (based, however, on

the same fundamental plan) in the shape of the gastropod shell, ranging from the Cowries (so well suited in size and shape for use as primitive money), in which the spire is generally concealed by the body whorl in the adult, and the flattened spire of the Carrier shell (*Xenophora*), to the greatly elongated spire seen for example in the Spindle shells (*Fusus*).

The material on the opposite side of the case deals on somewhat similar lines with the Pelecypoda (Fig. 2). The centerpiece is a greatly enlarged model showing the internal organs of the fresh-water mussel *Anodonta cygnea*, such features as the mantle, gills, foot, intestine, heart, gonads, and anterior and posterior adductor muscles being clearly displayed and labeled. The shells on view show the remarkable range of color, from light yellow to dark purple specimens, found within one species of scallop of the genus *Aequipecten*, while another beautiful color display is provided by *Tellina radiata* of the West Indies, well and deservedly known as the Sunset Shell. Shells of widely different shape are also shown, including *Spondylus powelli* of West Africa in which the valves are of tremendous thickness; this shell, standing upright, shows well the powerful hinge connecting the two valves. The most remarkable specimen as regards shape is the Watering-pot Shell (*Aspergillum*) which is not really a shell at all but a limy tube within which the two small valves of the shell proper are enclosed after the animal has outgrown them. The bottom block in this exhibit is devoted to man's use of the bivalve shell for decorative purposes. In the center is the valve of a pearl oyster into which had been inserted, as is the practice in the Far East, tiny figures of Buddha made of metal foil. These gradually become coated with a nacreous layer, and the mother-of-pearl Buddhas are then cut out from the shell. To the left of this are two valves on which figures and patterns have been engraved, cameo fashion, and to the right, two valves which have been ground down to the mother-of-pearl layer, in which various decorative designs have been cut.

One end of the case is devoted to the cephalopods and shows, above, models of attractively colored squids and a specimen of "cuttle-bone." A drawing of the internal anatomy indicates the position in the body of the gizzard, anus, heart, ink-sac, internal shell or cuttle-bone, and other organs. Below is a fine example of the shell which the female Paper Nautilus carries at the expanded tips of her upper arms, along with two models of the male, one with the hectocotylus arm fully extended. On the floor of the case, a complete shell of the Pearly Nautilus is amplified by two preparations to illustrate its internal septa and chambers. In this as in other sections of the exhibit, the material and labels do not supply answers to all the questions they suggest, which in an era of spoon-fed instruction may be thought a good thing.

At the opposite end of the case are examples of the Tusk or Tooth

Shells (Scaphopoda), from the large Elephant's-Tusk Shell of the Philippines to smaller species found around parts of the Welsh coast; and the Chitons (Amphineura), showing a range of size from half-an-inch up to about nine inches, with a preparation of the eight calcareous valves disarticulated.

It is appropriate that this short contribution from the National Museum of Wales should deal with Mollusca, because the Department of Zoology possesses the extensive and well-known conchological collection bequeathed by J. R. le B. Tomlin, and formed by the amalgamation of his own collection with that of J. Cosmo Melvill. This contains numerous type specimens from all over the world, besides series illustrating stages in growth and specimens notable for their rarity and beauty, such as the famous *Conus gloria-maris*. But these are for the specialist. The exhibit here described conveys, it is believed, to the ordinary visitor something of the stimulus to be derived from the beauty and the scientific interest of the Mollusca.

The Preparation of Biological Museum Specimens by Freeze-Drying: II. Instrumentation

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In a previous article published in CURATOR (Meryman, 1960), a technique was described by which biological specimens could be dehydrated from the frozen state with complete maintenance of physical detail and shape without the necessity of alteration or entry into the specimen. The purpose of this second article is to provide as much information as possible regarding theory, design, materials, and the cost of equipment for preparing biological museum specimens by freeze-drying.

THEORY OF FREEZE-DRYING

When a biological specimen is dried from the non-frozen state, shrinkage and distortion result when the forces of surface tension compress the specimen as the total amount of water is reduced. If the specimen is frozen prior to the onset of drying and the water is removed directly from the solid state, these surface tension effects are eliminated, and shrinkage does not take place. The function of the freeze-drying process is to remove water from the biological solution directly from the solid to the vapor phase.

The process of freeze-drying can conveniently be subdivided into three steps. The first of these is the transfer of water from the solid to the gaseous phase at the surface of the ice crystals throughout the specimen. The second step is the transfer of this water vapor from the vicinity of the ice

crystal to the surface of the specimen, passing through the already dried portions which increase in thickness as drying proceeds. The third step is the final removal of water vapor from the system to make way for the continuing release of vapor from the specimen. These three aspects of drying are discussed in detail below.

The Conversion of Water from Solid to Vapor: An ice crystal is composed of countless numbers of water molecules arranged in an orderly lattice. Each water molecule is confined in its position by the force fields of its neighbors, and within these confines it indulges in rapid random motion. For a molecule at the surface, there is always a possibility that one of its random motions will be sufficiently violent to project it past the restraining forces out of the confines of its position. When very large numbers of molecules are involved, the possibility of this escape becomes a statistical probability. Because the magnitude of the random motion of the water molecule increases with increasing temperature, the probability that it will escape also increases. Thus one can predict the number of water molecules per unit area that will escape from the surface of an ice crystal at any given temperature. This process is reversible, and a molecule of water vapor striking a suitable spot on the crystal with the appropriate orientation and energy will stay in place as part of the crystalline structure. Obviously the probability that this will happen also depends on the concentration of vapor molecules surrounding the crystal. The higher the concentration, the more chance that suitable collisions will occur. At any temperature there will be a fixed concentration of vapor that will produce a rate of return equal to the rate of departure. The pressure of this equilibrium concentration of vapor molecules is referred to as the equilibrium vapor pressure. A table of vapor pressures over ice at various temperatures is provided elsewhere in this article (Table 1).

When a molecule leaves the constricting confines of the crystal and becomes a vapor molecule with vastly increased mobility, it then possesses more energy. This energy must be acquired from the environment as heat. In other words, a fixed amount of heat is consumed by a molecule which transfers from the solid to the gaseous phase. When the process is reversed and a vapor molecule condenses to a solid, the identical amount of energy is released. This energy is referred to as latent heat. For water the latent heat of sublimation is approximately 670 calories per gram, a calorie being equal to the amount of heat required to raise one gram of water one degree Centigrade. It can be seen that very large amounts of energy are involved in this transition from solid to vapor. In many freeze-drying operations, particularly the large-scale drying of pharmaceuticals and foodstuffs, the drying rates are high, the total amount of heat required is very large, and much of the engineering effort in this industry is expended in attempts to improve the transfer of heat to the drying boundary within the speci-

men. As will be seen later, this problem is almost eliminated in the freeze-drying of museum specimens because of the very slow drying rates involved.

Vapor Transfer from the Ice Crystal to the Specimen Surface: If one imagines a specimen in the process of drying, it will have a shell of material that has already dried while the interior remains frozen. Drying will be taking place from a boundary between frozen and dried that regresses into the specimen as drying proceeds. All vapor that sublimes from the ice crystals must traverse this dried shell. A water vapor molecule wanders through the dried shell quite independent of any external force, ricocheting from one obstacle to another, whether the obstacle be the structure of the dried shell or another vapor molecule. If the concentration of vapor on one side is greater than that on another the molecule will make more collisions in the former direction and will thus tend to progress in the direction of lesser concentration. This is the *only* force propelling a vapor molecule through the dried shell. Only because of the existence of a higher concentration of water vapor at the drying boundary compared with that at the specimen surface will there be a net motion of water vapor towards the surface through the specimen.

There are two ways by which the concentration gradient within the specimen can be steepened. One is to reduce the concentration of water vapor at the specimen surface; the other is to increase the vapor pressure at the drying boundary. Because ice has a fixed vapor pressure at any given temperature, the only way by which the internal vapor pressure can be increased is by raising the temperature. The limit is the temperature at which slight melting begins and the frozen specimen acquires sufficient plasticity to begin to shrink. The internal temperature and vapor pressure are therefore fixed at a maximum permissible temperature. For the preparation of museum specimens, this temperature is between –10° and –15° C. If histological integrity is desired, the temperature must be maintained below –30° C. to prevent extensive crystal growth.

Removal of Water Vapor from the Specimen Surface: If the concentration of water vapor at the surface of the specimen increases, the concentration gradient between the drying boundary and the surface will decrease. Because this is the driving force that moves water vapor through the dried shell, the maintenance of a low water vapor pressure at the specimen surface is a primary aim of freeze-drying apparatus, which must be achieved by providing some means of capturing water vapor as well as some means of encouraging efficient transfer of water vapor from the specimen to the point of capture. Water vapor traps fall into three classes: chemical desiccants, refrigerated condensers, and vacuum pumps competent to handle water vapor. The chemical desiccant has the disadvantage that it can absorb only a limited amount of water before its own vapor pressure

begins to rise appreciably. Then it must either be discarded or be removed from the system and regenerated by heating. Refrigerated condensers are the most efficient pumps for water vapor. They can handle tremendous quantities of water at very high rates. As the vapor pressure of the ice that forms on the condenser surface is a function of temperature, the condenser temperature will determine the water vapor pressure in the drying chamber.

Vacuum pumps are manufactured with a design characteristic referred to as gas ballasting. This permits water vapor to be passed through the pump without condensing in the pumping oil. When this aspect is part of the pump design, a desiccant or refrigerated condenser can be eliminated and water vapor can be removed directly through the pump. The limitations to this method of water vapor removal are considerable and are discussed in a subsequent paragraph on vacuum pumps.

If a cold trap or desiccant is simply placed in the same chamber with the specimen, a vapor pressure difference will exist between the two, and water vapor will diffuse from the specimen to the condenser. However, when this process takes place at atmospheric pressure, the rate of diffusion of water vapor molecules is vastly impeded by the interference of air molecules. The average distance that a molecule can travel before hitting another is called the mean free path. At atmospheric pressure the mean free path of a water vapor molecule is roughly 0.005 micron (Table 2). If the transfer of water vapor from the specimen to the condenser is to be more efficient, the mean free path should be longer so that fewer collisions are involved in the traversal of this distance, which means simply the reduction of the pressure of air by evacuating the space with a vacuum pump. The average mechanical vacuum pump can, in practice, produce a vacuum of the order of 10 microns (10^{-2} mm. Hg). This subject also is discussed in more detail in the section on vacuum pumps.

The important concepts to understand are:

The water vapor pressure surrounding an ice crystal is a fixed function of its temperature.

The water vapor diffuses through the dried shell of the specimen only because of a difference in water vapor concentration between the inside and the outside. The water molecule is "unaware" of the existence of a vacuum outside the specimen and is uninfluenced by it. Its motion is wholly random.

The purpose of the vacuum in the chamber is to facilitate the transfer of water vapor from specimen to trap or pump by reducing the obstacle of residual air molecules.

The desiccant or cold trap is introduced to trap water vapor in order to maintain a low water vapor pressure in the system, to encourage the diffusion of water vapor from within the specimen.

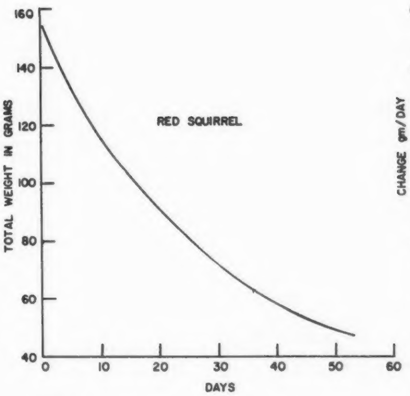

Fig. 1

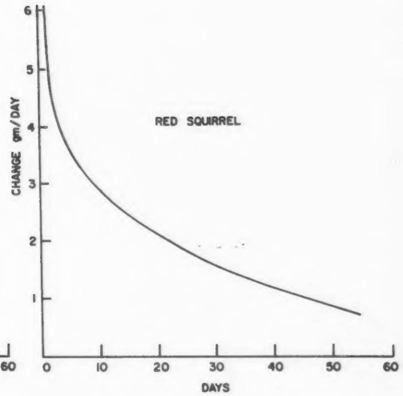

Fig. 2

WATER VAPOR OUTPUT AND DRYING TIME

Inasmuch as the purpose of freeze-drying is to remove water vapor and the aim of the apparatus is to do this efficiently, it is essential that one have a reasonably accurate idea of the amount of water involved in the drying of museum specimens and the rate at which it must be handled. Table 3 is reproduced from a previous paper and gives a general idea of the amounts of water removed from various types of specimen. The wide range of water content can be seen even from this meager assortment, ranging from a high of seventy-seven per cent for the dace to forty per cent for the toad. The total quantity of water ranges from 244 grams for the gray squirrel to 3.9 grams for the garter snake. However, because the capacity of the drying system for the handling of water is measured in grams per hour, the time factor must be introduced. In order to obtain a figure that will be useful, the water output per day must be determined.

It should be recognized that the rate of water removal is not constant. The greatest amount is removed early in the drying cycle, when the dried shell is thinnest, and approaches zero with the completion of drying. Figure 1 is a reproduction of a weight change curve demonstrating the manner in which weight is lost as a function of drying time. In Figure 2 the

Fig. 1. Specimen weight plotted against time of drying for a red squirrel.

Fig. 2. Data from Figure 1 replotted in terms of rate of weight loss in grams per day against day of drying cycle. The rapid drying rate during the first week is clearly shown.

information from Figure 1 has been recalculated to show the *rate* of weight loss as a function of time. It is this latter figure that is of the most significance in calculating the requirements of a drying system, and obviously it is a factor under the control of the operator. If he loads the chamber simultaneously with a large number of fresh specimens, the rate of

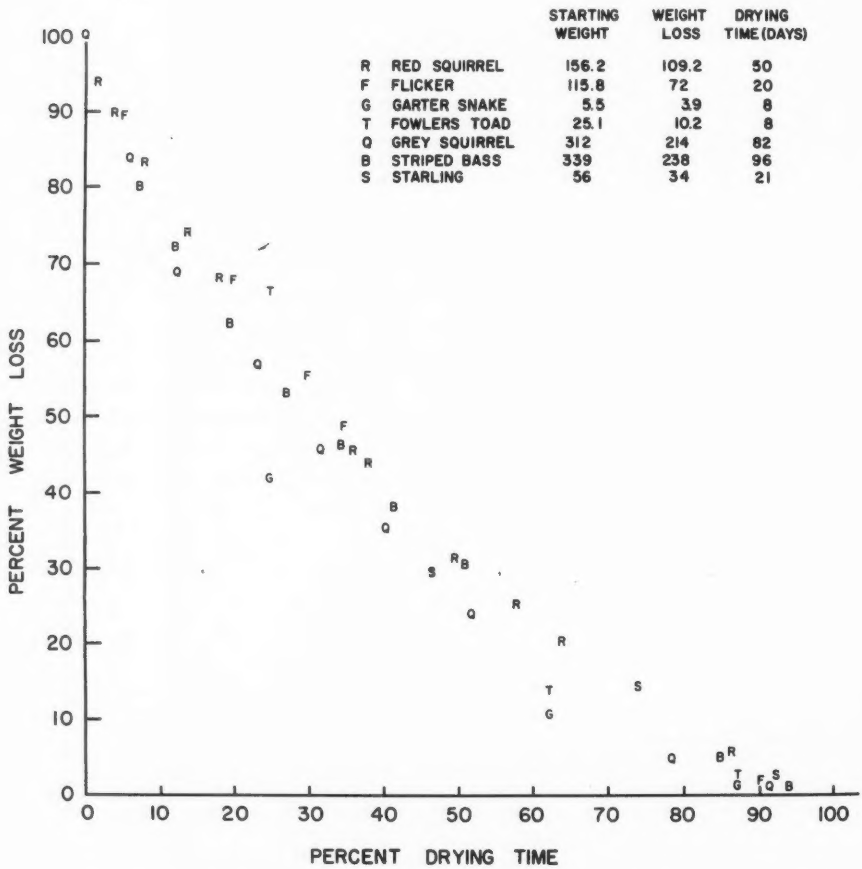

Fig. 3. Graph plotting, for different specimens, the per cent of water remaining against per cent of drying time elapsed. In effect, this device enables the direct comparison of a variety of weight change curves like those of Figure 1 when the weights and drying times may be vastly different. That the curves show such similar shapes despite the wide variations in absolute quantities involved reassures one that a prediction of drying curves will not be difficult once sufficient data on various species have been tabulated.

water vapor production will be very high during the first few days. If, however, he staggers the introduction of specimens, he can carry a considerably heavier load of material without exceeding the vapor handling capacity of the system. For example, ten squirrels introduced simultaneously under the conditions shown in the graph would release sixty-one grams of water the first day. At the end of one week the daily loss would be thirty-two grams and in three weeks would be down to twenty grams. It would obviously be a simple matter to space the introduction of specimens with these considerations in mind if maximum loading were desired.

Figure 3 is a composite graph showing, for an assortment of specimens, the percentage of water lost as a function of percentage of total drying time. This chart is very revealing, as it demonstrates a remarkable consistency in the behavior of a variety of specimens, particularly as the selection of the end point of drying can be rather an arbitrary matter. Although there is indeed a substantial acceleration of weight loss during the first ten per cent of the drying cycle and a retardation during the last ten per cent, the rate of weight loss during the main part of the drying cycle is remarkably constant. This points up the degree to which the relative impermeability of the epidermis, a constant factor, dominates the kinetics of drying, despite the fact that the drying boundary is becoming progressively deeper within the specimen and the vapor must travel across an increasing thickness of dried shell. This epidermal resistance, being fixed and unvarying, tends to hold vapor loss to a linear function of time. For this reason the curves in Figure 3 appear closer to a straight line than to the exponential function that one would expect. As a rough estimate, it is probably safe in practice to divide the weight of water in the specimen by the time required for drying in order to obtain an estimate of the amount of water evolved per day during all but the beginning and end of the cycle.

Advance estimates of drying times must be based on experience. Tables 3 and 4 include calculations of days of drying per gram of total weight and per gram of water removed as well as the inverse: the grams removed per day. When records of this sort are kept, a pattern on which predictions can be based will inevitably emerge.

The values for drying times cited in the previous paragraphs are based on specimens with an unbroken epidermis. As this represents so great an impediment to vapor transfer, much-reduced drying times can be achieved by perforating the skin or even removing it on the back side. Obviously, eviscerating a specimen will also drastically alter drying time.

With the sort of calculations described, it is a simple matter to approximate the weight of water per day that will be evolved from a given assortment of specimens. Obviously there will be wide variation in rate of water loss, depending on the character of the material, ranging from mammals with their thick epidermis through the fungi which are relatively porous

and lose their water rapidly, and, ultimately, to pure ice in which the rate of sublimation is limited only by heat input and the capacity of the pumping system.

The figures for drying time that have been used in the preceding discussion were derived from experiments in which the pressure within the drying chamber was maintained between 100 and 200 microns. Because the efficiency of the apparatus and the degree of loading of the chamber can markedly affect this figure, the influence of these factors on drying time should be mentioned.

Obviously the most rapid drying will take place when the water vapor pressure in the chamber is zero. The higher the water vapor pressure at the specimen surface, the less will be the concentration difference between outside and inside and the slower will be the diffusion of water vapor through the dried shell. If the water vapor pressure at the specimen surface equals the vapor pressure of ice at the specimen temperature, no drying will take place. The effect of overloading a system beyond its capacity for removing water vapor will be simply to allow a build-up of water vapor pressure in the drying chamber and a reduction in drying rate. As the temperature of the specimen is maintained by refrigeration, no harm will be done other than to delay the drying process. The relationship between chamber pressure and drying efficiency is discussed in the section on vacuum pumps.

APPARATUS DESIGN

Specimen Chamber: There are only two basic requirements for the specimen chamber: it must be vacuum-tight and it must be refrigerated. Complicating the construction of a vacuum-tight container is the provision of a large access door and construction that will withstand a negative pressure of fifteen pounds per square inch. The refrigeration system should be capable of reducing the wall temperature of the chamber to at least –15° C. (5° F.), and preferably to –30° C. (–22° F.). Specific design considerations are as follows:

Specimen Chamber Construction: Although fifteen pounds per square inch may not seem high pressure, when large areas are involved the forces become considerable. For example, a flat vacuum chamber door eighteen inches in diameter must support a total force of 3800 pounds, or nearly two tons. The total force on the exterior of a cylindrical container three feet in diameter and four feet long is approximately fifty-six tons. Obviously, structural strength is no minor element in the construction of these chambers. It should also be obvious that the larger the chamber, the more acute become the structural problems. The cylindrical form is the most practical from an engineering standpoint. Rectangular containers require heavy-gauge walls for small-sized chambers and heavy reënforcing for large.

The fabrication of chambers up to twenty-four inches in diameter is relatively simple and economical. The cylinder walls are simply a length of steel pipe of the desired diameter. The ends must be turned square and smooth and the edges chamfered. The ends of the cylinder are steel plates three-eighths to one-half of an inch thick, which are either ground, turned, or sanded smooth where contact is made with the ends of the cylinder. It is advisable not to have the back or bottom end welded to the cylinder, as the production of a vacuum-tight welded seam is not within the capabilities of the average welder. A rubber gasket seal is more apt to be vacuum tight and is easily prepared. One approach is to slit a piece of rubber tubing lengthwise and fit it over the end of the cylinder. The ends of the tubing should overlap and be tapered to provide a uniform thickness. The large pressures created by evacuation will compress the gasket to form an excellent seal. Alternatively, a groove can be turned in the end plate into which the cylinder will fit. A gasket cut from flat rubber stock can be cemented into the bottom of the groove for the vacuum seal. Such a chamber can be obtained for a cost of approximately $125.

Larger chambers can no longer be constructed from standard tubing and must be fabricated specially. The cost of such construction can become prohibitive, and it is advisable at least to find a supplier of large cylinders manufactured for some other purpose. Intermediate sizes are obtainable in the form of pressure cans used in paint spraying. The largest of these that is commercially available has internal dimensions of twenty-two by thirty inches in length and retails for about $350.[1] Manufacturers of autoclaves can supply much larger chambers both in cylindrical and rectangular shape, complete with a vacuum-tight end opening and a double wall around the sides of the chamber through which refrigerated liquid can be circulated. The cost of such chambers is of the order of several thousand dollars.

It is necessary to connect a vacuum line to the specimen chamber. The best method of forming a vacuum-tight joint between the pipe and the chamber is to permit a steel pipe to project slightly through the tank and have it welded in place on the inside. The bead need only be partial to give the joint structural stability. The vacuum seal is then made by flowing a bead of soft solder around the outside of the joint. In small installations in which the vacuum line is an inch or less in diameter, only a short nipple is needed to which rubber or reënforced plastic tubing can be joined. For larger lines, standard plumbing brass tubing is easiest, all joints being soft-soldered. When a solder joint is formed for vacuum use, both surfaces should be tinned completely and wiped free of flux first; then they are joined and additional solder is flowed into the joint.

[1] Binks Manufacturing Company, 3114 Carroll Avenue, Chicago 12, Illinois.

Refrigeration and Insulation: Heat transfer within an evacuated chamber is largely by radiation, and there will be radiative heat transfer between a specimen and all surfaces in a direct line of sight with it. As the drying rate of museum specimens is too slow to cause appreciable specimen cooling, the entire chamber must be uniformly refrigerated. The use of refrigerated shelves in an otherwise warm chamber is unsatisfactory for this application.

The insulation of the chamber either must be non-porous, as in foamed plastics, or must be hermetically sealed on the outside. If this precaution is not taken, the water vapor present in the air will diffuse through the insulation and condense as ice on the wall of the chamber. This process progresses with time, until eventually the insulating layer is totally filled with ice, and its insulating properties are completely destroyed. The easiest procedure is to use the rigid plastic foams such as Styrofoam. This material comes in boards up to six inches in thickness. It is not permeable to water vapor, and external hermetic sealing is not necessary. An insulation superior to this but requiring slightly more skill and preparation is foamed-in-place plastic. For this, the chamber is suspended in an outer mold which can be fabricated of any material. The plastic is mixed and poured into the space between the chamber and the outer shell, where it foams and sets into a one-piece impermeable insulation. The outer form can be subsequently removed if desired.

As there is no production of heat within the chamber, the only load on the refrigeration system is the heat leak through the insulation. This figure determines the capacity of refrigeration apparatus that is required. All commercial insulating materials have a K factor which describes their insulating value. The heat leak in B.T.U. (British thermal units) per hour can be determined by multiplying the K factor times the surface area of the chamber in square feet and the temperature difference between inside and outside in degrees Fahrenheit and dividing this product by the insulation thickness in inches. Table 5 lists some characteristic figures for common insulating materials.

After the total heat leak has been calculated, it is possible to select the proper size of refrigeration compressor. Table 6 lists typical capacities for standard fractional horsepower refrigeration units. It is customary to double the calculated heat exchange figure, so that a fully adequate margin of safety will be provided.

There are two ways by which the chamber can be cooled. It can be wrapped with tubing, which will form the evaporator of the refrigeration system, or a liquid can be cooled by the refrigerator and in turn circulated through the tubing around the chamber. We are inclined to prefer the latter approach, as it is possible to obtain a closer control of the temperature and a more uniform temperature throughout the length of tubing,

less refrigerant gas is required, and two or more chambers can be run from the same cooling system. The purchase of a heat exchanger and circulating pump will increase the cost to some degree. If an autoclave chamber with double wall is used, cooled liquid can be circulated between the walls.

Placing the chamber within a commercial freezer is the simplest solution for the small installation and completely eliminates the necessity for refrigerating and insulating the chamber itself. The only fabrication necessary with such an arrangement is the opening of a hole through the side of the freezer to bring the vacuum line out to the vacuum pump. One should always obtain from the manufacturer advice regarding the location of refrigeration coils or plates within the freezer wall before the hole is bored.

Water Vapor Trap: There are three methods of removing water vapor from the system after it leaves the specimen: chemical desiccants, refrigerated cold trap, and the gas-ballasted vacuum pump. The chemical desiccant has disadvantages in that it will remove up to a fraction of its weight in water and must then be removed and regenerated. If the amount of water to be absorbed is large, either the quantity of the desiccant or the frequency of its recharging becomes impractical. In circumstances in which the quantity of water is small, a gas-ballasted vacuum pump may well suffice. Although chemical desiccants were used in our original experiments, subsequent experience has shown that they are not the best solution for this particular application. The use and choice of the gas-ballasted vacuum pump will be discussed in a subsequent section.

The refrigerated condenser is probably the most efficient water vapor pump known. Depending on the size and temperature used, very large quantities of water can be condensed and very low vapor pressures maintained. There are two important considerations to be borne in mind when designing a refrigerated condenser. First, the driving force that moves water vapor from the ice crystal through the dried specimen shell and through the vacuum chamber to the refrigerated trap will ultimately be determined by the difference in vapor pressure between the ice crystal and the refrigerated condenser. Reference to Table 1 will demonstrate the fixed relationship between water vapor pressure and temperature. It is clear from this table that a modest temperature difference between specimen and condenser results in a substantial difference in water vapor pressure but that increasing the temperature differential by lowering condenser temperature produces proportionately less gain in pressure differential.

For example, with a specimen at –10° C. and condenser at –30° C., there is a vapor pressure difference of 1.66 mm. Hg. If the condenser

were at absolute zero, the pressure differential would be only 1.95 mm. Hg. This twenty-degree temperature differential has produced a pressure difference which is eighty-five per cent of the maximum possible. If the condenser temperature be decreased to –40° C., the vapor pressure differential becomes 1.85 mm. Hg, or ninety-four per cent of the maximum. An increase of fifty per cent in temperature differential has yielded an increase of only nine per cent in vapor pressure differential. A further lowering of condenser temperature to –50° C. increases the vapor pressure differential by another three per cent, and it is obvious that a point of diminishing returns has long since been reached. It is clear therefore that in condenser design efforts to produce very low temperature are a waste of time and money, as the cost per B.T.U. exchanged increases rapidly as refrigeration temperature is decreased. Temperatures of –30° C. to –40° C. are well within the range of conventional fractional horsepower refrigeration units operating on F-12 or F-22.

The second point to be remembered in designing the condenser is that the rate of water loss from the specimen will be very low so that the loading on the condenser coils will place no particular demands upon the refrigeration apparatus. The amount of energy involved in converting the water vapor in the vacuum chamber to ice on the condenser surface will be identical to that involved in the original sublimation. For each gram of water condensed 670 calories, or 2.66 B.T.U., must be removed. In view of the fact that the water transfer will rarely exceed a few grams per hour and will usually be far less than that, the B.T.U. involved in vapor condensation will be negligible compared with the capacity of refrigeration units as shown in Table 5. The heat leak through the insulation of the condenser chamber should be calculated exactly as was done for the specimen chamber. Such calculations will show that a very modest refrigeration unit will usually be fully adequate.

Because the loading on the refrigeration unit will be so modest, the condenser may well run at a very low temperature in any case. Under these conditions a very small amount of refrigerant will be circulated through the compressor. Some types of sealed unit compressors use the flow of refrigerant gas to cool the compressor motor. This type should be avoided for this application, as there is always the danger of motor burn-out when a very small amount of refrigerant circulates at very low temperature.

When condensers are used under heavy loading applications, with large quantities of water condensed at a very high rate, there may be a significant temperature differential between the condenser coils and the surface of the ice on the coils. When the rate of condensation is low, the amount of heat transferred across the ice thickness becomes correspondingly small, and such a temperature differential becomes insignificant.

The condenser chamber should generally be a separate chamber from that in which the specimens are contained. A separate chamber is necessary because of the difficulty in shielding specimens from thermal radiation to the condenser if it is placed in the same chamber, which would result in specimens that might be partially at a substantially lower temperature than that intended, with a corresponding increase in drying time. All the comments regarding construction of the specimen chamber apply to the condenser chamber, save that it need only be large enough to contain the evaporator coils of the refrigeration equipment. A spiral winding of copper tubing suspended inside the condenser chamber is

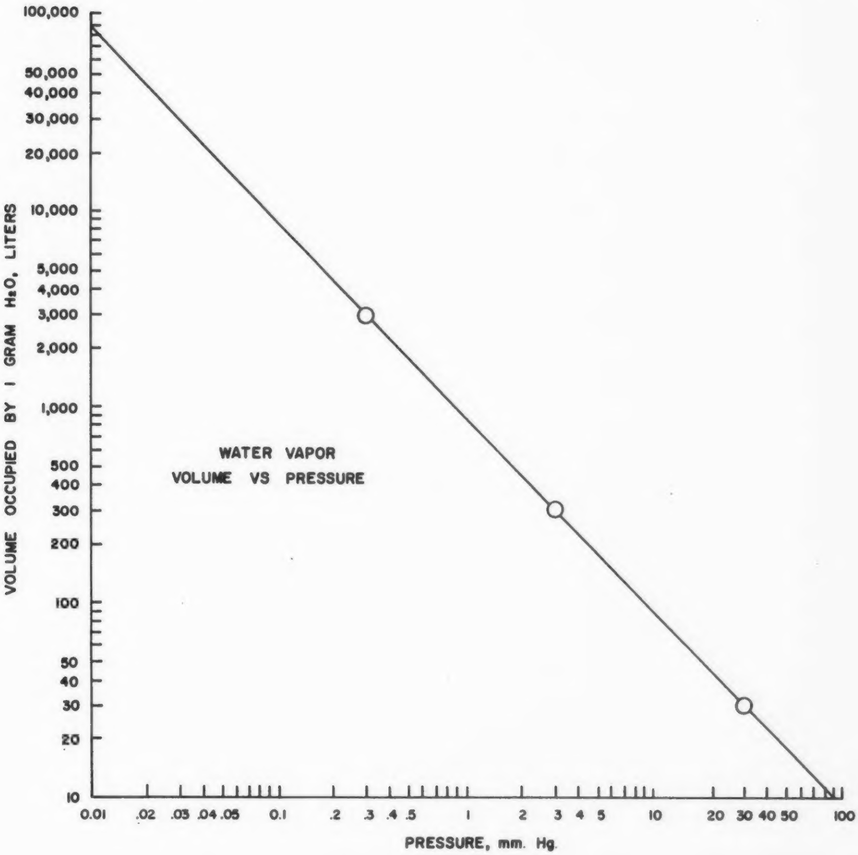

Fig. 4. The relationship of water vapor volume to pressure. The two are inversely proportional, so that doubling the pressure reduces to half the volume occupied by a gram of water. One cubic foot equals 28.3 liters.

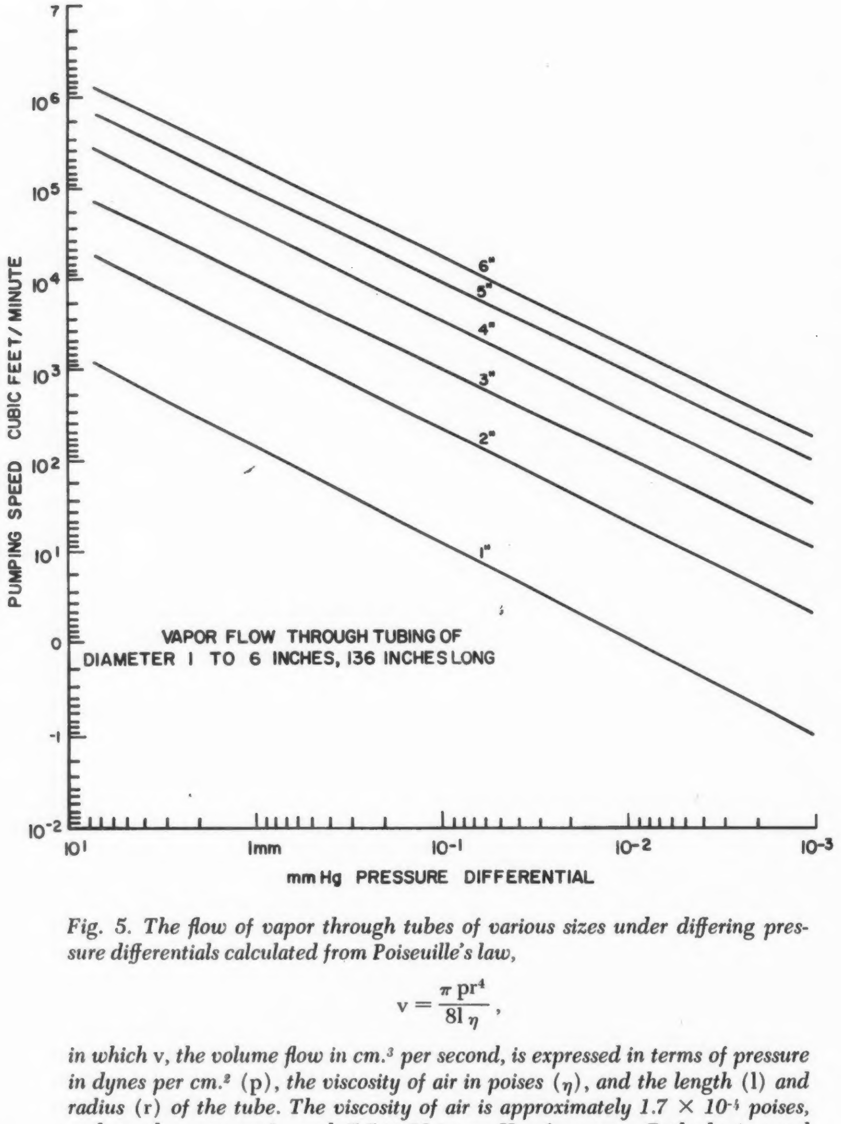

Fig. 5. The flow of vapor through tubes of various sizes under differing pressure differentials calculated from Poiseuille's law,

$$v = \frac{\pi\, p r^4}{8 l\, \eta},$$

in which v, the volume flow in cm.^{3} per second, is expressed in terms of pressure in dynes per cm.^{2} (p), the viscosity of air in poises (η), and the length (l) and radius (r) of the tube. The viscosity of air is approximately 1.7 $\times$ 10^{-4} poises, and one dyne per cm.^{2} equals 7.5 $\times$ 10^{-4} mm. Hg of pressure. Both abscissa and ordinate of the graph are logarithmic scales. From the graph the capacity of a tubing in cubic feet per minute at any given pressure differential can be read directly. For example, with a differential of 100 microns (10^{-1} mm.) between ends of the pipe, a one-inch tube will carry ten cubic feet per minute, while a three-inch tube will carry 1000 cubic feet per minute. The curves are calculated to tubing 100 cm. long. Doubling the length reduces the capacity by half.

quite adequate. A drain cock should be provided at the bottom of the condenser. The pipe to the vacuum pump should not enter at the bottom of the chamber unless proper precautions are taken to prevent water from getting into the vacuum line when the condenser is defrosted. Defrosting is necessary only when the evaporator coils have become coated with ice to a thickness of a half inch or more. A shut-off valve between the specimen chamber and the condenser chamber is convenient but expensive. Most large-bore valves suitable for vacuum use cost in the vicinity of $100 or more. The need for a valve can be avoided by breaking vacuum in the system and plugging the vacuum port from the inside of the specimen chamber with a large stopper or a rubber ball, then closing the specimen chamber door to keep out atmospheric moisture. After the condenser is defrosted and the chamber drained, operating temperatures should be restored in the evaporator coils before the stopper is removed from the vacuum line and the system pumped down again. This procedure can be done with partially dried specimens in the chamber, provided refrigeration of the specimen chamber is maintained.

Vacuum Pumps: When a refrigerated condenser is employed as a vapor trap, the only function of the vacuum pump is to reduce the pressure of non-condensable vapor (air) to an operating value and to maintain this pressure in the face of such small leaks as may exist in the system. In addition, most specimens contain about five volumes per cent of non-condensable gases in solution which are released as drying progresses. In general the dominant requirement of the pump is that it bring the chamber down to operating pressure within a reasonable period of time. The formula establishing the relationship between pumping capacity, chamber volume, and ultimate vacuum is reproduced in Table 7, as are actual calculations from this formula for some specific pumps and chamber sizes, and approximate price ranges for pumps of the indicated capacity. All pumps described are two-stage, gas-ballasted pumps. We consider it unwise to use a vacuum pump that is not gas ballasted in a freeze-drying system, because failure of the trap is always possible, with disastrous effects on the pump. A single-stage pump is not usable because its ultimate vacuum is reduced by the gas ballasting to an unsatisfactory degree.

It has been mentioned repeatedly that under certain conditions the refrigerated vapor trap can be eliminated and water vapor removed directly through the vacuum pump. In order to determine whether or not such a process is feasible, it is necessary first to determine the approximate amount of water to be released each minute from the total specimen load of the chamber. By reference to Figure 4, one can then determine the volume that this amount of water vapor will occupy at a number of different operating pressures. It can be seen from this figure that the

volume occupied by a gram of water is inversely proportional to the pressure. This is of considerable help in keeping the system operating effectively under varying conditions of load. For example: a system operating at 150 microns would deliver two hundred cubic feet of vapor to the pump for each gram of water sublimed. If the amount of water sublimed were doubled and the pump was incapable of handling the increased volume, the pressure in the chamber would rise. However, as the pressure rose the volume occupied by a unit weight of water vapor would decrease, and at a pressure of 300 microns two grams of water would occupy the same volume as did one gram at half the pressure. In other words, the effect of overloading a system in which water vapor is removed by the vacuum pump is simply to increase the operating pressure in the specimen chamber. As the differential between the water vapor pressure in the chamber and the vapor pressure of ice in the specimen provides the driving force to move water vapor through the system, one can readily estimate the probable decrease in efficiency resulting from an increase in chamber pressure. In the example just cited, an increase in chamber pressure from 150 microns to 300 microns with specimen temperature at –10° C. would result in a reduction of vapor pressure differential from 1.80 mm. Hg to 1.65 mm. Hg, or a reduction of a little more than eight per cent, which demonstrates that the effect of increasing the water vapor load may not be so deleterious as expected, as long as a good pressure differential is still maintained.

The vacuum pumps themselves are rated in cubic feet of free air displacement per minute. The figure is derived from physical measurement of the volume displaced by the pump in operation. When the amount of air pumped in actual operation is measured, it is found to be slightly less than this figure, owing to the impossibility of completely emptying the chamber on each revolution of the pump. As the pressure of the space pumped upon is reduced, the pumping speed of the pump declines slightly, generally falling off rapidly when it reaches a pressure about ten times that of its rated ultimate vacuum. For a single-stage mechanical pump with gas ballast the ultimate pressure is usually limited to about 200 or 300 microns, and the pumping speed falls off rapidly at one or two millimeters, making the single-stage, gas-ballasted pump inadequate for freeze-drying. The two-stage pump is generally rated with an ultimate vacuum of from 0.1 to 1 micron, although in practice 10 microns is generally an acceptable figure. With gas ballast the rated ultimate pressure ranges from 1 micron to 10 microns. However, pumping speed usually begins to fall off at about 100 microns, which can be considered a satisfactory working pressure for the freeze-drying operations herein considered. The use of an oil diffusion pump or mechanical booster pump to extend the pumping capacity or ultimate vacuum of the mechanical pump

is entirely superfluous. The high cost of such additional apparatus is not justified by the modest increase in pressure differential between chamber pressure and the vapor pressure of the specimen ice.

Vapor Flow Through Tubing: One last consideration in the design of a dynamic vacuum system is the impediment to flow that may be introduced with connecting links of pipe between chambers and pump. Fluid flow in vacuum systems is generally divided into viscous and molecular flow. Molecular flow is defined as that occurring at pressures at which the mean free path is longer than the average distance between walls of the conducting tubing. Reference to Table 2 will show that the mean free path does not become comparable to tubing size until a pressure of 1 micron is achieved. We are therefore concerned only with viscous flow in this particular application of vacuum systems.

The relationship between pumping speed through a tube and the various factors influencing it is approximated by Poiseuille's law. Figure 5 provides the formula, the constants involved, and some characteristic figures calculated from this formula. It will be seen from this graph that the restriction of tubing to vapor flow becomes significant only when the volumes to be moved are very large, the tubing quite small, or the pressure differential small. It should also be noted that the volume transfer through the tube is proportional to the fourth power of the tube radius, which means that a modest increase in tube size can produce a very substantial increase in volume conduction. There is no evidence that bends in the tubing introduce much more resistance to flow than straight tubing in this pressure range.

Vacuum Gauges: Although not essential to operation, a vacuum gauge is necessary if one is to have any real knowledge of conditions within the chamber. The most familiar gauge is the McLeod gauge ($75 to $100), which is a device by which the pressure in the chamber is compared to a perfect vacuum by measurement of the height of a column of mercury supported by this differential pressure (a direct measurement of millimeters of mercury). The McLeod gauge suffers from the fact that water vapor may be condensed during operation of the gauge, so that measurements of atmospheres with high water vapor content may be substantially in error. It also is not capable of being read continuously.

The simplest and easiest gauges for the pressure ranges involved here are the thermocouple and the Pirani gauges. Both operate on the principle that heat from a filament is lost more effectively when the pressure is higher, permitting more conduction of heat by vapor molecules. The thermocouple gauge contains a hot wire, the temperature of which is measured by a thermocouple. The Pirani gauge measures the temperature of the wire by monitoring the electrical resistance of the wire itself. Both are rugged and convenient. The Pirani gauge sells for $60 to $100 or

more; the thermocouple gauge is slightly higher in price. Bourden gauges, direct reading manometers, and the Dubrovin gauge are not sensitive enough. The cold cathode (Philips) gauge and the ionization gauge are for much higher vacuum work and are insensitive in the range of interest herein discussed.

CONCLUSION

In general, commercial freeze-drying apparatus is not suitable for the preparation of biological museum specimens. Most commercial freeze-drying equipment is designed either for the preparation of histological sections in the laboratory and has a specimen chamber volume of a liter or less or is designed for the drying of pharmaceuticals which are placed on shelves that may be either refrigerated or heated. The drying of museum specimens demands that the entire chamber be uniformly refrigerated to the drying temperature. Possibly some large freeze-drying units can be adapted for this purpose, but it must be made quite clear to the manufacturer that the specimens must be completely surrounded by refrigerated surfaces of uniform temperature and that the refrigerated condenser not be in direct line of sight with the specimen. In general, the cost of large, commercial, freeze-drying equipment is figured in many thousands of dollars and would be beyond the reach of organizations which might benefit most from its use. Even the simplest possible apparatus specifically designed for museum specimen drying, consisting of refrigerated chest, specimen chamber, and vacuum pump,[2] retails currently for approximately $2,000, so that one certainly cannot say that this is the poor man's solution to taxidermy. However, for the museum that indulges in any volume of specimen preparation, labor costs are hardly inconsequential, and such an organization might do well to apply a moment to pencil and paper in considering what sort of preparations might be better handled by freeze-drying. For those whose budgets or talents lead them to do-it-yourself construction, the detail of this paper should suffice. A very abbreviated instruction sheet also has been prepared specifically for application to school science projects (Meryman, 1961). Additional hints and helpful discussion can be obtained from texts on laboratory technique (Strong, 1953; Braddick, 1954).

To reiterate observations made in the previous paper (Meryman, 1960), we feel that this technique should not be taken as an affront to the skill of the taxidermist or as a threat to his existence. His range is extended, his output is increased, the messier aspects of his trade are minimized, and perfection becomes more nearly attainable. To the museum preparator whose ambitions are of this nature, we submit this new technique.

[2] Canal Industrial Corporation, 4937 Cordell Avenue, Bethesda 14, Maryland.

ADDENDUM

The foregoing article has described in great detail the engineering requirements and considerations involved in the construction of apparatus for freeze-drying museum specimens. The author wishes to point out that he is neither a taxidermist nor a museologist but a biophysicist engaged in research on the freezing and freeze-drying of living cells. The development of this technique has been an unplanned byproduct of otherwise basic research. In this article and its predecessor he has exhausted his fund of information on the preparation of museum specimens. Questions regarding special museum problems such as poisoning against insects, maintenance of special pigments, or the preservation of curious forms of life are beyond his experience. His hope is that readers of this article will accept the challenge to investigate for themselves the wide range of museum display problems in which this technique may be of assistance.

TABLE 1. Equilibrium Vapor Pressure Over Ice at Various Temperatures

(Pressure is measured in terms of the height in millimeters of a column of mercury that the pressure can support.)

TEMPERATURES IN DEGREES CENTIGRADE	VAPOR PRESSURE OVER ICE IN MM. HG
0°	4.58
–5°	3.01
–10°	1.95
–15°	1.24
–20°	0.776
–30°	0.286
–40°	0.0966
–50°	0.0296
–60°	0.00808

TABLE 2. The Relationship Between Pressure and Mean Free Path for Water Vapor

(Mean free path is generally defined as the average distance that a gas molecule can travel before colliding with another gas molecule.)

PRESSURE	MEAN FREE PATH IN MM.
10 mm. Hg	0.0034
1 mm. Hg	0.034
100 microns	0.34
10 microns	3.4
1 micron	34

TABLE 3. Approximate Drying Times, Weight Loss for Various Specimens, and Calculation of the Per Cent of Starting Weight Lost as Water

SPECIMEN	DRYING TIME IN DAYS	STARTING WEIGHT IN GRAMS	FINAL WEIGHT IN GRAMS	PER CENT OF WATER AS WEIGHT
Red squirrel	28	110	50	54%
Red squirrel	42	156	48	69%
Gray squirrel	63	376	132	65%
Flicker	28	116	44	62%
Fowler's toad	9	25	15	40%
Garter snake	8	5.5	1.6	71%
Horned dace	7	31.7	7.3	77%
Horned dace	4	11.9	2.7	77%

TABLE 4. Calculations Derived from Table 3

(The ratio between grams of specimen weight—starting weight, dry weight, or weight of water—and the number of days required for drying are given. The reciprocal, days per gram, is also shown. If figures of this sort are kept on all specimens, one would find a definite relationship developing between one or the other of the values from which a prediction of drying time could be made on the basis of species and total weight or anticipated dry weight. The weight of water removed per day is a value necessary for the management of chamber loading.)

SPECIMEN	GRAMS PER DAY			DAYS PER GRAM		
	STARTING WEIGHT	FINAL WEIGHT	WATER	STARTING WEIGHT	FINAL WEIGHT	WATER
Red squirrel	3.9	1.8	2.1	0.26	0.56	0.47
Red squirrel	3.8	1.1	2.6	0.26	0.88	0.39
Gray squirrel	6.0	2.1	3.9	0.17	0.48	0.26
Flicker	4.15	1.6	2.6	0.24	0.64	0.385
Fowler's toad	2.8	1.7	1.1	0.36	0.60	0.91
Garter snake	0.69	0.2	0.48	1.45	5.0	2.1
Horned dace	4.5	1.05	3.5	0.22	0.95	0.285
Horned dace	3.0	0.7	2.3	0.33	1.5	0.435

TABLE 5. Properties of Typical Insulating Materials

(The K factor permits the calculation of heat transfer through insulation. The heat leak in British thermal units per hour is determined by multiplying the K factor by the area in square feet and the temperature difference between inside and outside in degrees Fahrenheit, then dividing this product by the thickness of the insulation in inches. One B.T.U. is the amount of heat required to raise a pound [pint] of water one degree Fahrenheit.)

MATERIAL	K	B.T.U. PER HOUR THROUGH 4-INCH INSULATION OF CYLINDRICAL CHAMBER 3 FEET IN DIAMETER BY 4 FEET IN LENGTH (52 SQUARE FEET), EXTERIOR TEMPERATURE AT 70° F.	
		Interior Temperature –10° F.	Interior Temperature –40° F.
Glass wool	0.29	380	435
Cork board	0.30	390	450
Rock wool	0.26	340	390
Styrofoam[a]	0.23	300	345
Isofoam[b]	0.145	190	217

[a] Manufactured by the Dow Chemical Company, Midland, Michigan.
[b] Manufactured by E. I. duPont de Nemours and Company, Inc., Wilmington, Delaware.

TABLE 6. Typical Maximum Capacities of F–12 Refrigeration Compressors of Sizes from One-Quarter to One Horsepower

(Ambient temperature is assumed at 90° F. Cost of compressors ranges from about $100 for one-quarter-horsepower to $200 for one-horsepower compressors, not including expansion valve and evaporator tubing.)

HORSEPOWER	B.T.U. PER HOUR				
	5° F.	0° F.	–10° F.	–25° F.	–40° F.
1/4	1900	1700	1300	750	350
1/3	2275	2050	1550	950	445
1/2	3500	3175	2450	1550	1000
3/4	5100	4600	3550	2250	1400
1	7200	6500	5100	3350	2300

TABLE 7. Pump-down Times for Various Pump and Chamber Sizes

(The time required to evacuate a chamber depends on the volume of the chamber, the capacity of the vacuum pump, and the ultimate vacuum of which it is cabable. The relationship is expressed in the following formula:

$$t = \frac{V}{S} \log_e \left(\frac{P_1 - P_o}{P_2 - P_o} \right)$$

in which t is the pumping time in minutes, V is the chamber volume in cubic feet, S is the pump speed in cubic feet per minute, and P_1, P_2, and P_o the starting pressure (in this case, 760 mm. Hg), the final pressure desired, and the ultimate pressure, respectively, that the pump is capable of producing. The pumping time required to produce pressures of 1 mm., 500 microns, or 100 microns for three different sizes of chamber and five sizes of pump are calculated.)

	Chamber Volume									Approximate Cost of Pump
	3.5 Cubic Feet (1.5 x 2 Feet)			10 Cubic Feet (2 x 3 Feet)			28 Cubic Feet (3 by 4 Feet)			
Final pressure in mm. Hg	1	0.5	0.1	1	0.5	0.1	1	0.5	0.1	
Pumping capacity in cubic feet per minute										
1	23	26	32	67	74	90	186	205	253	–
2	12	13	16	33	37	45	93	103	126	$240
3	7.7	8.5	11	22	25	30	62	68	84	$270
4	5.8	6.4	7.9	17	18	23	47	52	63	$330
7	3.3	3.6	4.5	9.5	11	13	27	29	36	$345
10	2.3	2.6	3.2	6.6	7.4	9.0	19	21	25	$775

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A New Temporary Exhibit System

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A new, flexible, temporary exhibit system has been designed by the present authors for the Treasure Room of the new Interchurch Center on Riverside Drive in New York City. The unit of poles and attached cases used in the Treasure Room is a unique structural system. Though compression poles and attachments have been in use for some time, the particular design illustrated here is new to the museum field. The flexibility in the arrangement of cases, which can be attached in either a horizontal or a vertical position, is one of the most valuable merits of the system. Another feature is the ease with which the black masonite case backs can be removed or installed. These case backs have a removable, protective, plastic cover. They were designed to hold valuable documents and papers and, when not on exhibit, can be stored individually in a specially designed storage rack.

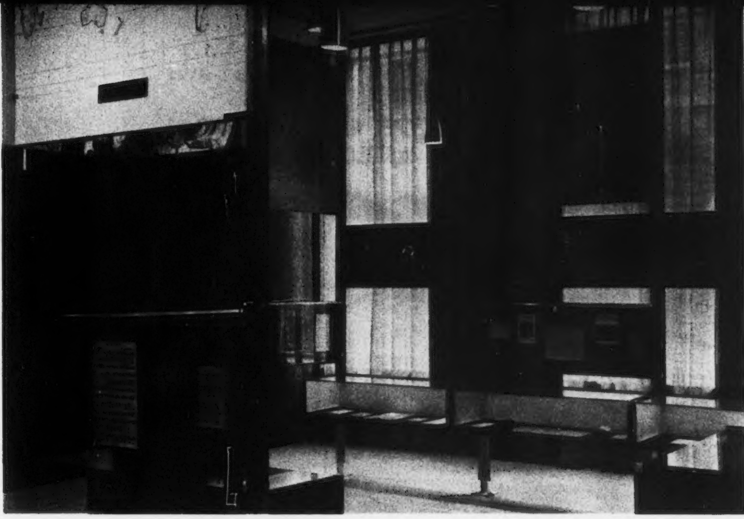
The exhibit poles are of extruded aluminum, cruciform (with four-inch arms) in cross section, notched at set intervals on all faces, which permits the attachment of cases on each face. Any possible location of the poles in the exhibit area is indicated by brass strips embedded in the terrazzo floor, as well as by equispaced slots in the ceiling (made up of unistrut channels), thus establishing a grid pattern which makes any number of combinations of layout possible. The poles can be easily set and locked into position, by turning a jack screw at the top, once the pole is in the desired location. This can be done by two people and the use of a step ladder.

The cases can also be installed with a minimum of effort by two people by their lifting the case to the desired height and sliding the two hooks on the rear of the case into the slots of the pole. A slight downward pull locks the hooks and the case into position.

While the case is in a cantilevered position, its basic construction will take considerable punishment by visitors, though it is not advisable to allow museum visitors to lean upon it.

To add to the flexibility of future exhibits a trolley-duct lighting system was permanently installed, to complement the flexible exhibit units. Lights can be shifted to any desired location on the track by merely pushing the fixture with a long pole. Extra fixtures can easily be added if necessary.

In museums that carry on an active exhibition program, in which staff and funds are provided for the building of permanent displays, the administration must be well aware that this activity eats up a great deal of money. Permanent cases using expensive cabinetry or metal work and

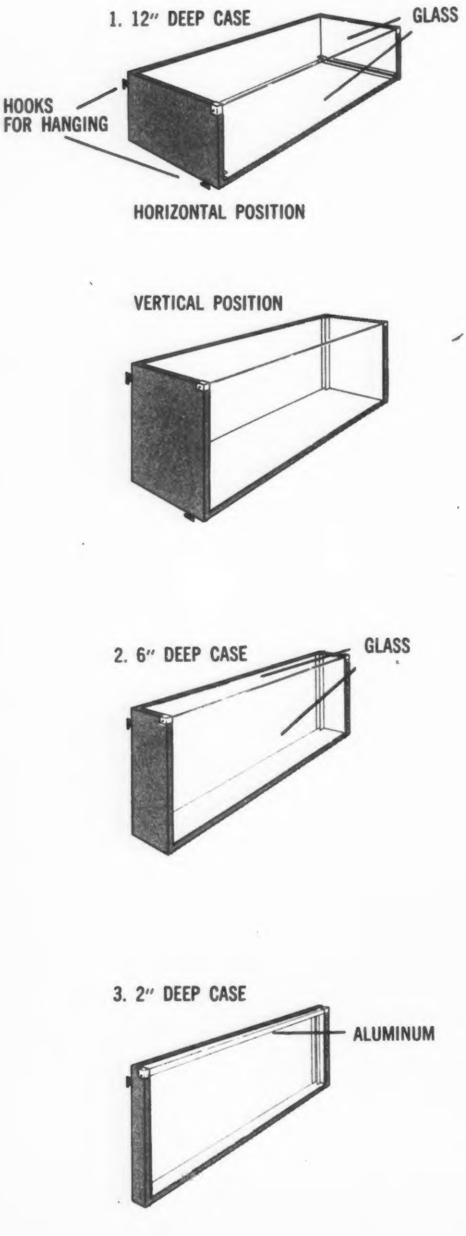


permanent lighting and wiring all emphasize such heavy expenditures; also space that is utilized for a permanent exhibit is lost for any other purpose for a long, long time. Further, the particular specimens or objects that are on view are not easily accessible for the research scholar, and many specimens and objects important for teaching or scientific exhibition can never be seen by the public for lack of space in which to show them, so are doomed to remain in storage.

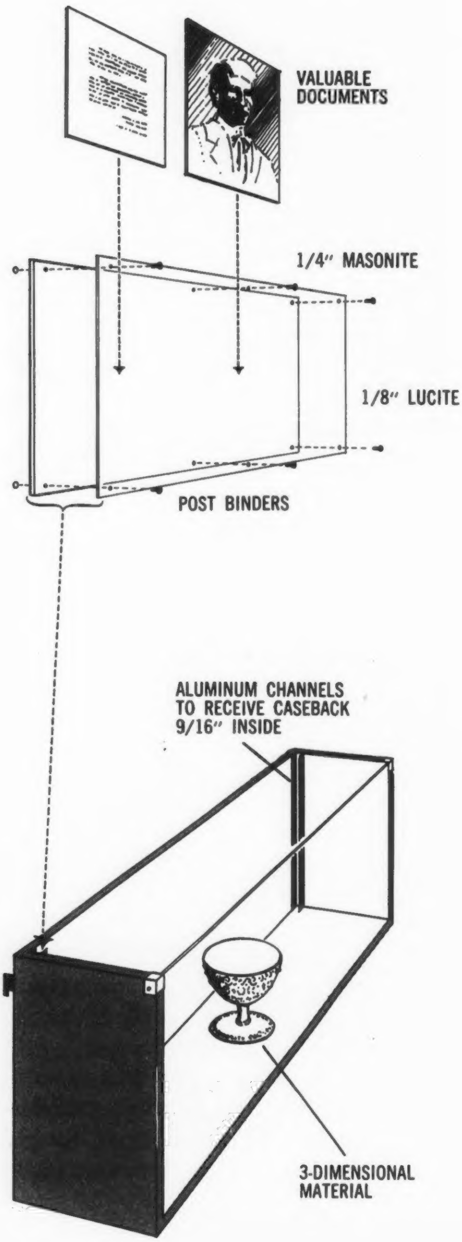
Some museums are awake to the problems of tight budgets, small staff, inadequate storage areas, and scant exhibition space, and hence emphasize the temporary exhibit and the changing exhibit. Not only do they avoid huge expenditure for permanent installations and the general problem of

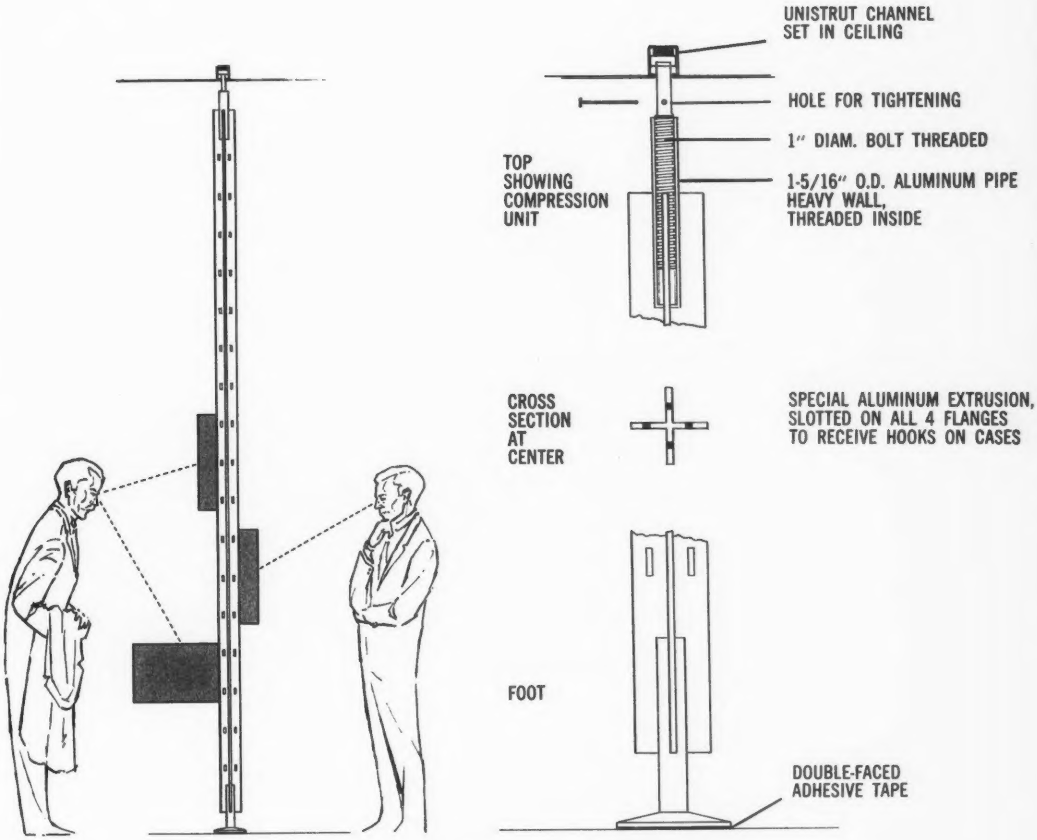
continued on page 180

THREE TYPES OF CASES, SHOWING HOOKS FOR HANGING; WAXED WALNUT EXTERIOR, WHITE LACQUER INTERIOR.

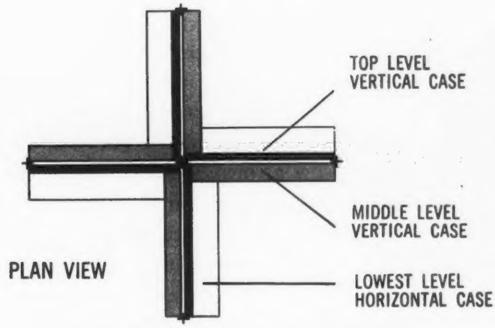


CASE BACK DESIGN AND INSTALLATION IN CASE

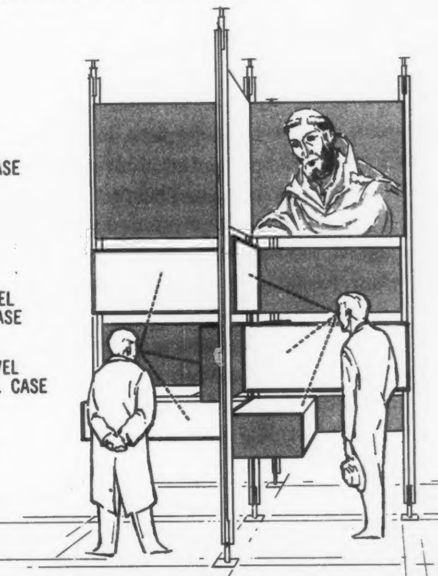




ALUMINUM POLE SUPPORT FOR CASES: ELEVATION AND DETAILS



CASE ATTACHMENT SHOWING MAXIMUM USE,
USING FIVE POLES



lack of space, but a new liveliness is added to their public image by the presentation of timely and exciting exhibitions installed in a flexible system. Thus, on a rotation basis, such museums are able to show more of their permanent collections in a smaller space, and the visitor is able to receive continued stimulation by viewing a constant flow of new exhibits. This approach, which is finding many adherents among newly constructed museums, points out the functional advantages of extreme changeability, whereby money and space are saved. It may cost almost as much money to design and construct a good flexible exhibit set-up, including cases and panel system, as a permanent installation, but the flexible installation can be used again and again.

A New Technique in Nature Trail Signs

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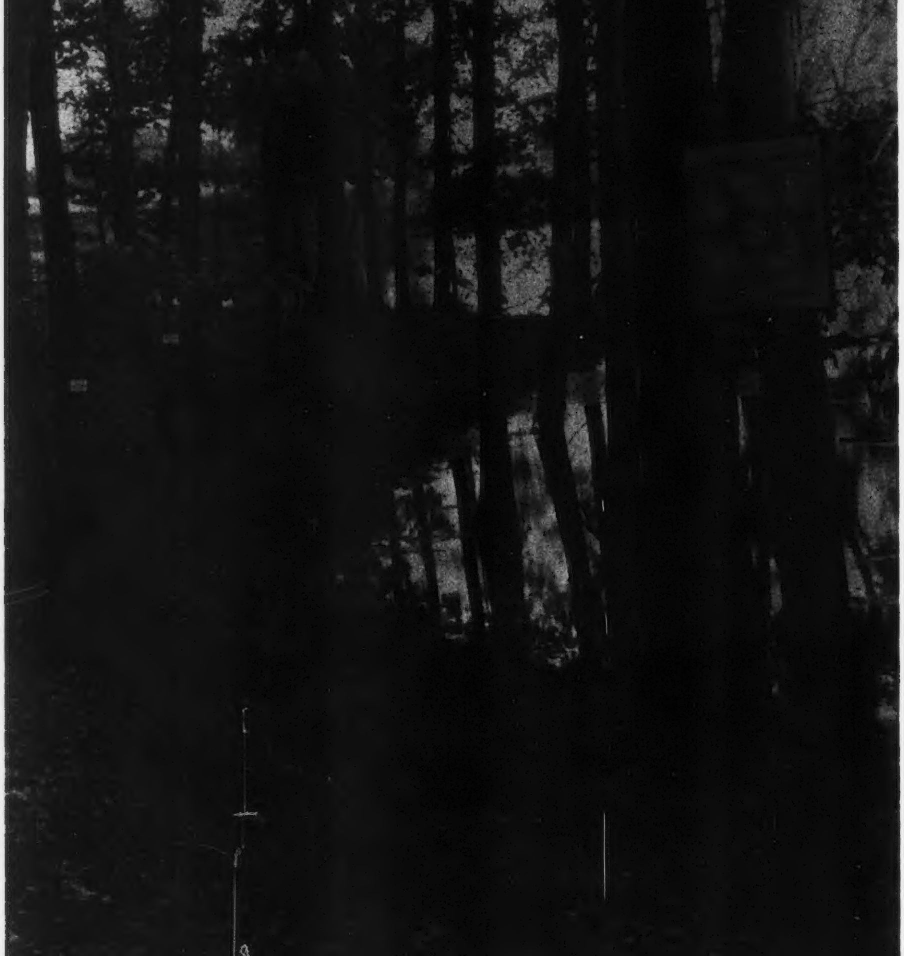
THE AMERICAN MUSEUM OF NATURAL HISTORY
AND EUGENE J. DRAGO

Through the generosity of Mrs. Lewis S. Thompson, of Red Bank, New Jersey, the Department of Education of The American Museum of Natural History instituted during 1959–1960 a program of educational services to three New Jersey state institutions—the Reformatory for Women at Clinton, the Marlborough State Hospital, and the Arthur Brisbane Child Treatment Center at Allaire. Together the several services constituted the "New Jersey Project."

Among the activities undertaken was the labeling of natural features of the grounds. At the Marlborough State Hospital this took the form of two nature trails, one in the vicinity of a pond and dealing with pond life, flowers, and birds, the other in a wooded area and dealing with trees. At the Child Treatment Center at Allaire and the Women's Reformatory at Clinton, the labels were placed on trees about the grounds and dealt with trees and birds.

At the outset, several considerations had to be met: the labels were to be exposed to the weather for one season and possibly several; many of them were to bear colored illustrations; they were to be of varied background colors, if feasible; and they were to be inexpensive. In short, they were to be as durable, attractive, and cheap as possible.

The conventional materials used in the making of outdoor labels and signs presented the following problems: wood warps; sheet metal is expensive; paper is not durable; small quantities of many colors of paints are expensive; unpainted surfaces of wood, wood products, and metal are unattractive. Our final decision was to make the labels of the most implausible material—paper! For very little cost we obtained pastel-tinted commercial printing papers in the following colors: blue, green,



gray, pink, salmon, and two shades of yellow. In addition, we used white typing paper from office stock. The texts of the labels were lettered in India ink on the paper. Illustrations were usually added, either by cementing pictures cut out of inexpensive books, such as the Golden Nature Guide series, or by spatter-printing over leaves or paper cutouts, using poster colors. Spatter-printing had the advantage of adding new color dimensions, as well as providing opportunity for interesting design.

The next problem was to put the paper signs in a form suitable for outside exposure. We solved this problem by having them laminated in plastic by a commercial firm. We were quoted an initial price of one dollar per sign for lamination, but this was reduced to half because of the quantity. The plastic-laminated signs were then affixed to backboards of a pressed wood material produced under the trade name Duolite. The thickness of the Duolite was one-eighth of an inch. To affix the labels we first tried several preparations, including Duco cement, shellac, and an unnamed formula for plastics used extensively by the Department of Exhibition of the American Museum. None was satisfactory. A solution to the problem came in the form of a tape with two adhesive surfaces and sold under the trade name of Kleenstik. As a check, test signs in finished form were submersed in water for one hour each day for six weeks, then for an uninterrupted period of seventy-two hours. At the end of the test period the damage was negligible, and the plastic could not be pulled away from the backboard without complete destruction of the plastic.

The finished signs were approximately five inches by ten inches, except for a few ten-by-ten signs. Some of the signs were attached to trees by the use of bell wire; others were attached to upright posts. From the period of March to December, the time of writing, all signs have withstood the elements satisfactorily, the only damage being some fading of colors where the labels were exposed to strong sun.

Comments

(At the symposium on "The Role of the Research Museum in Science," comments were specifically invited from Derek J. de Solla Price and A. E. Parr. Manuscripts for the comments were not available for publication at the time the main articles appeared in CURATOR, *1961, volume III, number 4, pages 310–360. These comments appear below.*—EDITOR)

I am glad that Dr. Multhauf has reminded you so appositely of the origin of the museum and the cabinets of curiosities of sixteenth and seventeenth century amateurs of science. Only the natural history parts of the collections have evolved smoothly from this beginning and have continued to serve the double function of research tool for working scientists and an object of more or less edifying delectation for the visiting public.

What, however, of the early collections of weird and wonderful physical and astronomical instruments and technological objects of curious artisanship? I should like to take Dr. Multhauf's lucid explanation that the non-natural history science museums have become meat for the historian and the historian of science and technology; I must draw one conclusion from his analysis, and I should like to tell you of one practical application.

My conclusion is that the museums of physical science have badly lost their way, much more so in the United States than ever in Europe. To fill a vacuum of unknown purpose and function these museums have been dubbed with an unfortunate combination of pedagogic function as an ever-open, one-shot classroom on the one hand, and as a permanent trade fair on the other. Since those who pay for museums demand something tangible for their money, such a situation was perhaps inevitable. I would not presume to declare it wholly bad. What is bad is that the old chief function of gathering wondrous artifices has tended to disappear. Perhaps this has happened because of the mistaken analogy that physical museums, like biological museums, should be operated by scientists; that assumption is wholly incorrect. It now seems clear, I feel, that whether or not physical science museums (and even planetariums) teach science, the fine pieces of apparatus exercise a considerable attraction for the public. In England it is the boast of the South Kensington Science Museum that just such relics of science have inspired many of the young scientists of today with their first awakening to their chosen profession. Still more important, in an age when science is becoming the dominant expenditure of manpower and resources of the nation and the source of our greatest contributions—intellectually as well as materially—the relics of science and their intelligent curating and exhibition give almost the only opportunity to preserve and help understand this part of our cultural heritage.

The place of the science museum is changing rapidly, and it is vital that some-

where in the world people should be discussing and preparing the way for seizing the new opportunities of service. It is vital that we do not allow expositions of the Palais de la Découverte type (as exemplified by that which is at present extending hospitality to us here at Boston, and its fellow at Chicago) to become the only type of physical science museum in the country. When I first came to this country I was shocked to find that, apart from the Smithsonian Institution, there were no science museums in America of the sort that I had found and delighted in throughout Europe. The Palais de la Découverte is meaningful only when it has the Conservatoire Nationale des Arts et Metiers behind it. These museums in Boston and Chicago have no real physical science museums behind them, and it is a pity that because of this lack their purpose is not wholly fulfilled. Incidentally a great number of important and historical pieces of apparatus are being junked, thrown away, and left in their dilapidation, unrecognized and uncared for, in a manner which is more vandalistic in the United States than in almost any other country in the world.

Dr. Multhauf has mentioned that the new situation for curators of physical science museums has been brought about by the rise of the history of science as an approved and autonomous scholarly discipline in American universities. There are now some thirty-five colleges in the United States where the history of science is taught as a regular course. In eight of these, doctorates are currently offered. At Yale, we have recently created a department of the History of Science and Medicine. It offers a complete program of undergraduate courses which in 1961 will be taken by at least two hundred students, of which two will be pioneers for a new major in the History of Science and Medicine. In our graduate courses we offer programs leading to master's and doctor's degrees, and in 1961 there will probably be about a dozen such graduate students taking these courses. We are proposing to offer in 1961, with the approval of Dr. Dillon Ripley, Director of the Peabody Museum, a special graduate course designed specifically to help such scientists, historians of science, and others who may be considering a museum career. The course description is as follows:

> *History of Science and Medicine 102B*
> *Seminar in History of Museums, Laboratories, Scientific Societies and Journals.*
> Lectures and seminars on the history of scientific organizations and institutions from the earliest times to the present day. This course will treat the social institution of science and the facilities needed by scientists. The course is also available to students in science wishing to pursue further the background of scientific museums (*see also* Zoology 176, Prof. Osgood, Museum Practice in Anthropology). Two hours, second term, Professor Derek J. de Solla Price.

In addition to this course we have as part of our normal program studies in the history of scientific instruments and all normal courses in the historical development of all the physical and biological sciences of technology and medicine. It is our devout hope that some students will be attracted by these courses and may be trained from the beginning as suitable persons to become curators of the physical science museums which we hope will arise to fill the vacuum in

this country. We hope too to be able to arrange with such museums, and in the first place with the Smithsonian Institution, for curators to be able to come to Yale for a sabbatical to pursue research and to join in our seminars and graduate instruction. In return, perhaps some of our graduate students might be available for work as summer interns so that they may discover the possibilities of a museum career. We look forward to a very interesting time in this work.

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The inclusion of museums of science and technology in our discussion has been very enlightening. Both Multhauf and Price have referred to the Palais de la Découverte in Paris as the prototype of something new among museums. Multhauf speaks of it as an "exposition"—without permanent archives of historical collections and with heavy reliance upon scheduled demonstrations rather than static exhibits—as distinct from a "museum" in the traditional sense, with its emphasis upon the accrual, maintenance, and study of collections. The existence of a conflict, and of the possibility of a separation between the archival and educational functions of, and among, the natural history museums has been pointed out before. Perhaps this comparison with the museums of the exact sciences and technologies may serve to bring the idea home. But first it seems necessary to introduce a refinement of definitions and of the classification of museums or of museum contents in regard to the exact sciences.

Actually our subject has three separate aspects. One is the instrumentation of scientific research. Another has to do with the contents of scientific knowledge. And a third is concerned with the application of science to human needs. Although both Multhauf and Price seem strongly oriented towards the need for museum collections and exhibits documenting the development of scientific apparatus, the European museums of which they speak most favorably are overwhelmingly devoted to the illustration of technology and technological progress through the application of science, with the instrumentation of science given a very slim role to play in their exhibits. One need only recall how a full-sized replica of a mining operation, usually that of a coal mine, has come to be almost as omnipresent in museums of science and technology as are the stuffed lions in museums of natural history.

There can be no doubt that it is generally most practical, and therefore as a rule highly commendable, to combine in a single institution the documentation of scientific instrumentation and of the application of science through technology. But it is quite unnecessary, illogical, and dangerous to confuse matters by seeming to merge the separate identities of the two topics in a single, blurred concept. What usually happens in these circumstances is that the history of scientific instrumentation receives the short end of the deal, and it would seem very desirable that there should be at least one museum devoted exclusively to

this topic alone, so that there would be one place where its message would be clear and unobscured by the superficially more sensational memorabilia of technology.

A second consequence of identifying or confusing instrumentation and application in dealing with the exact sciences is likely to be that the demonstration of the contents of scientific knowledge is pushed out of the nest altogether and may even be sniped at from the tree tops as it seeks to establish a home elsewhere.

It is to the task of familiarizing its visitors with the fundamental laws of nature that the pioneering Palais de la Découverte primarily addresses itself with its public demonstrations of experiments revealing basic principles of scientific knowledge. Multhauf[1] correctly defines the offerings of the Palais de la Découverte as being essentially in the nature of a laboratory course, but his assertion that it differs from university courses by being extended in space rather than in time may call for certain reservations. The claim is true, of course, in the sense that the Palais is able to conduct simultaneous performances of many different demonstrations that could only be given one at a time in the classroom. But in another and more important sense the contention is more likely to obscure than to clarify the true nature of the Palais de la Découverte.

In our country we have fallen into the habit of judging a museum's performance on the basis of the knowledge and understanding it is able to convey during a single visit. Number reached, rather than depth of influence upon the individual, is the measure that consciously or subconsciously colors all our reasoning. But it is perfectly clear that the messages of the Palais de la Découverte are aimed primarily at the repeaters. Casual visitors are welcomed chiefly in the hope that they may become new devotees, returning again and again, with a new appetite for learning that will grow by what it feeds on. From the point of view of such visitors the courses offered at the Palais de la Découverte are just as extended in time as they would be in any classroom. Since there are no educational prerequisites, the courses are more elementary and therefore shorter than they would be at the graduate level in a university, but that is another matter. The feeling of extension in space may also be fortuitously reënforced by the fact that demonstrations of so many different sciences are conducted under a single roof. But this arrangement is actually a cooperative concentration in space rather than an extension, although the over-all dimensions of such a multifaceted enterprise may invite the opposite impression.

But such comparisons with the laboratory courses of other educational institutions merely refer to the *modus operandi* of the Palais de la Découverte. More of the essence is the fact that the Palais is a museum for the exposition of ideas rather than the preservation and display of objects—an institution actively engaged in teaching, but also relatively limited to what can be actively taught, with comparatively little food for self-education beyond the scheduled activities. It is probably not wrong to say that the Palais de la Découverte is the first museum that has deliberately chosen for its repertoire the presentation of the contents of scientific knowledge, rather than the paraphernalia or the products

[1] CURATOR, vol. III, no. 4 (1960), p. 357.

of science.

The impact of this relatively new concept of museum functions is perhaps even more clearly shown in the comments of the critics than in the tributes paid by those converted to the cause. It cannot be considered without significance that Multhauf, who argues strongly for the traditional type of museum—documenting the history of science by the preservation of its implements—should entirely fail to mention the Conservatoire Nationale des Arts et Metiers, with its magnificent and fascinating collections of the inventions of man located in the same city as the considerably smaller Palais de la Découverte, which receives more space than any other institution mentioned by Multhauf.

Even more revealing is the statement by Price (above) that the Palais de la Découverte is meaningful only when it has the Arts et Metiers behind it. It seems difficult to believe that such a plea can be seriously intended. Are the thousands of classroom demonstrations offered every day in other types of educational institutions far removed from the backing of any such establishment as the Arts et Metiers not meaningful for that reason? Can the many sciences that do not depend on special instrumentation—and those that may indeed not require any complex implements at all—not be communicated in any meaningful manner owing to these features of their methodology? Can the force of gravity not be meaningfully demonstrated because Newton carelessly neglected to preserve the fallen apple for the historical collections of posterity? Three of the nine sections of the Palais de la Découverte are Biology, Medicine, and Microbiology, for which it would be difficult to find any backing in the historical collections of a museum of technology. For three other sections, Chemistry, Surgery, and Mathematics, the paraphernalia of the past would also have relatively little to contribute to our understanding of the current contents of scientific knowledge.

The relationship between the institution dedicated to the demonstration of scientific principles and the establishment devoted to the preservation and display of inventions for research or utility is one of division of labor rather than interdependence of functions within the proper educational sphere of each. And just as the "exposition" is limited to what can be actively taught, so is the "archive"—more passively holding out the richness of its resources as fuel for the processes of learning and of self-education—limited by the extent to which the development of scientific thought and knowledge is clearly and specifically reflected in the evolution of research equipment and of the practical inventions that follow the progress of science. It must also be pointed out that, when we accept the claim of the South Kensington museum that its "relics of science" (Price, above) have proved the first inspiration for many of the young scientists of today, we are equally bound to accept the identical claim made for the demonstrations in the Palais de la Découverte on the basis of similar records.

This question of teaching demonstrations versus reference collections for research and self-education also has a bearing upon the second point I wish to bring up. Through the words of all contributors to this symposium runs a strong implication that research is to be regarded as an institutional obligation and a personal duty. In another symposium, on college and university museums, Hubbell,

while expressing his belief in the research functions of university museums, also voiced his concern over the fact that proper university salaries could be obtained only by combining curatorial positions with appointments on the teaching faculty, or, at least, with teaching faculty ranks. Colbert and Fenton have both made the same observation in this discussion, and Fenton has specially added that the museums "had best advance their claim as educational establishments," and if they can demonstrate that they "are assets to the structure of higher education in America, and the public interest is sufficiently aroused, public support will be forthcoming."

Is it not high time that we took realistic cognizance of the fact that it is primarily as educators in educational institutions that we secure our positions, gain opportunity to do research, and obtain support for our museums? I have tried to develop this point more extensively in the article already quoted by Fenton and do not wish to repeat myself here, except to point out that the significance of the first part of the quotation is lost when it is followed by the suggestion that museum positions for research may offer an alternative to the treatment of research as a right instead of a duty in curatorial positions not specifically defined as research appointments. The first sentence in the quotation here referred to had to do with the historical fact that so long as The American Museum of Natural History expressed no interest in and made no mention of research by its own staff in the annual reports, the paid curatorial staff actually engaged in research grew from none at all to over thirty in response to the purely practical needs of collections and educational functions. After research was embraced as an ideal institutional obligation, and curatorial research became a regular target for pointing with pride in the annual reports, the research staff, instead of increasing by leaps and bounds at a greatly accelerated rate, actually showed no residual increase at all at the end of another forty years. In other words, Fenton's second alternative has already been tried by history and found wanting, except, of course, in the case of public museums connected with special research functions of an official kind, such as federal or state geological surveys or similar undertakings. We are in a very strong position so long as we rest our case on the simple and obvious truth that the museum, just like the university, cannot obtain the quality of personal service it needs for its educational functions and other "practical" obligations, unless it offers the right to do research—with ample allowance of time and adequate provision of space, equipment, and funds for the purpose—along with decent salaries and other personal rights and privileges.

We must also recognize that among the museums now developing there are many that may always continue to dedicate themselves exclusively to their educational functions, with no ambitions towards the accumulation of large storage collections behind the scene, and I venture to predict that there will actually be much less research done across the nation, if we try to insist upon the institutional obligation of all museums to do research, instead of merely pointing out that they will not be able to get the services they need unless they allow for the conduct of research by those they seek to engage.

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PICTURE CREDITS

Pages 111, 112, and 115, Otago Museum, Dunedin, New Zealand; page 119, Muséum National d'Histoire Naturelle, Paris; pages 120 and 137, Zoological Museum, Bergen; figure 4, page 121, Bo Bergstedt, Malmö Museum, Sweden; figure 5, page 123, Museum of Science, Boston; figure 6, page 123, Narodni Museum, Prague; figure 7, page 124, page 134, and page 135, Smithsonian Institution Museum of Natural History; page 126, British Museum (Natural History); pages 128, 129, and 130, Chicago Natural History Museum; page 132, Academy of Natural Sciences of Philadelphia; pages 148, 149, National Museum of Wales; all photographs in article beginning on page 175, Lee Boltin; all others, The American Museum of Natural History.